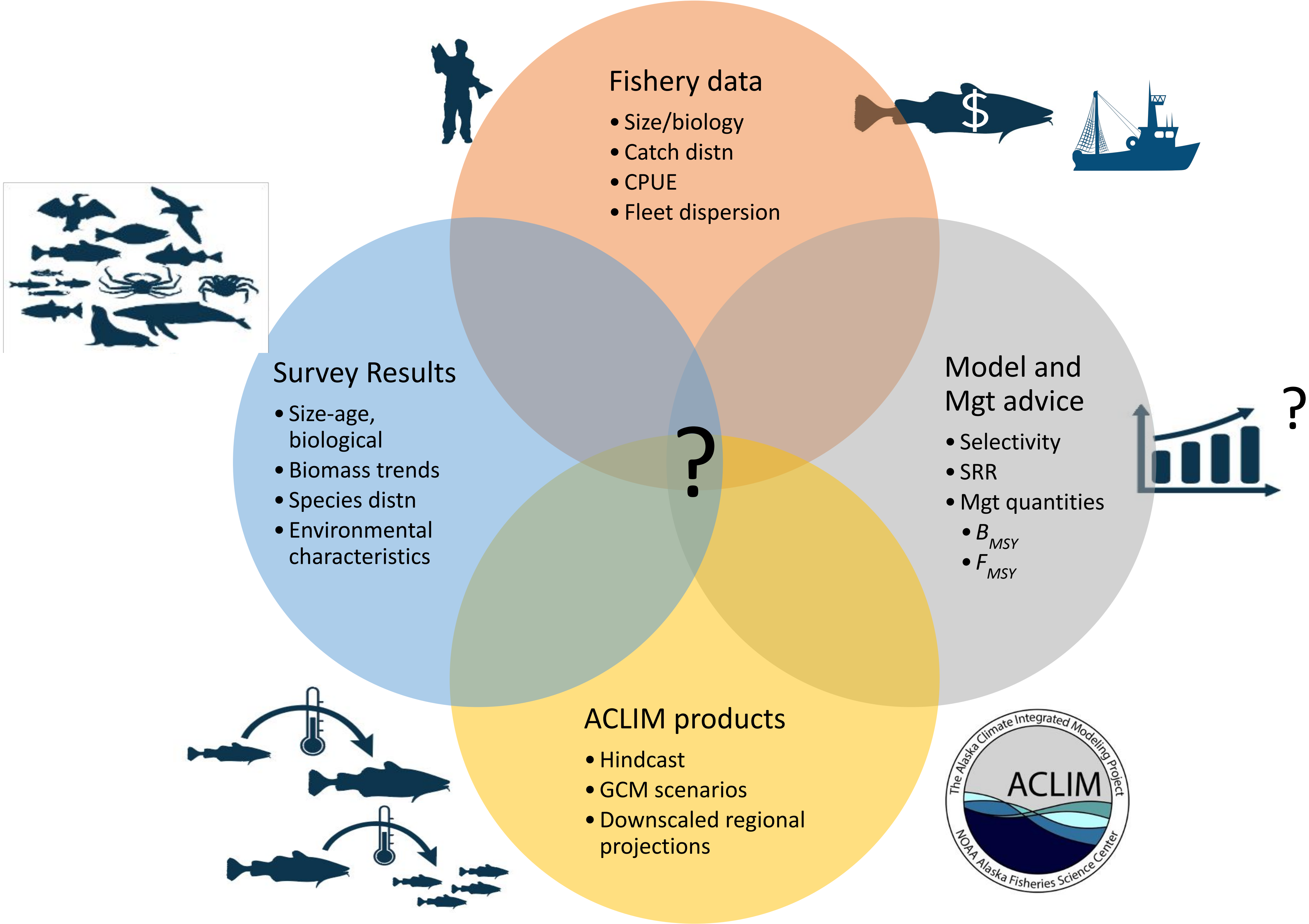
Perspectives on ways complex ecosystem projections can be applied in real-world fisheries management cases

Jim Ianelli

Alaska Fisheries Science Center

Early observations…


Fishery data
• Size/biology
• Catch distn
• CPUE
• Fleet dispersion
Survey Results
• Size-age, biological
• Biomass trends
• Species distn
• Environmental characteristics
Model and Mgt advice
• Selectivity
• SRR
• Mgt quantities
• B_{MSY}
• F_{MSY}
ACLIM products
• Hindcast
• GCM scenarios
• Downscaled regional projections
?
?
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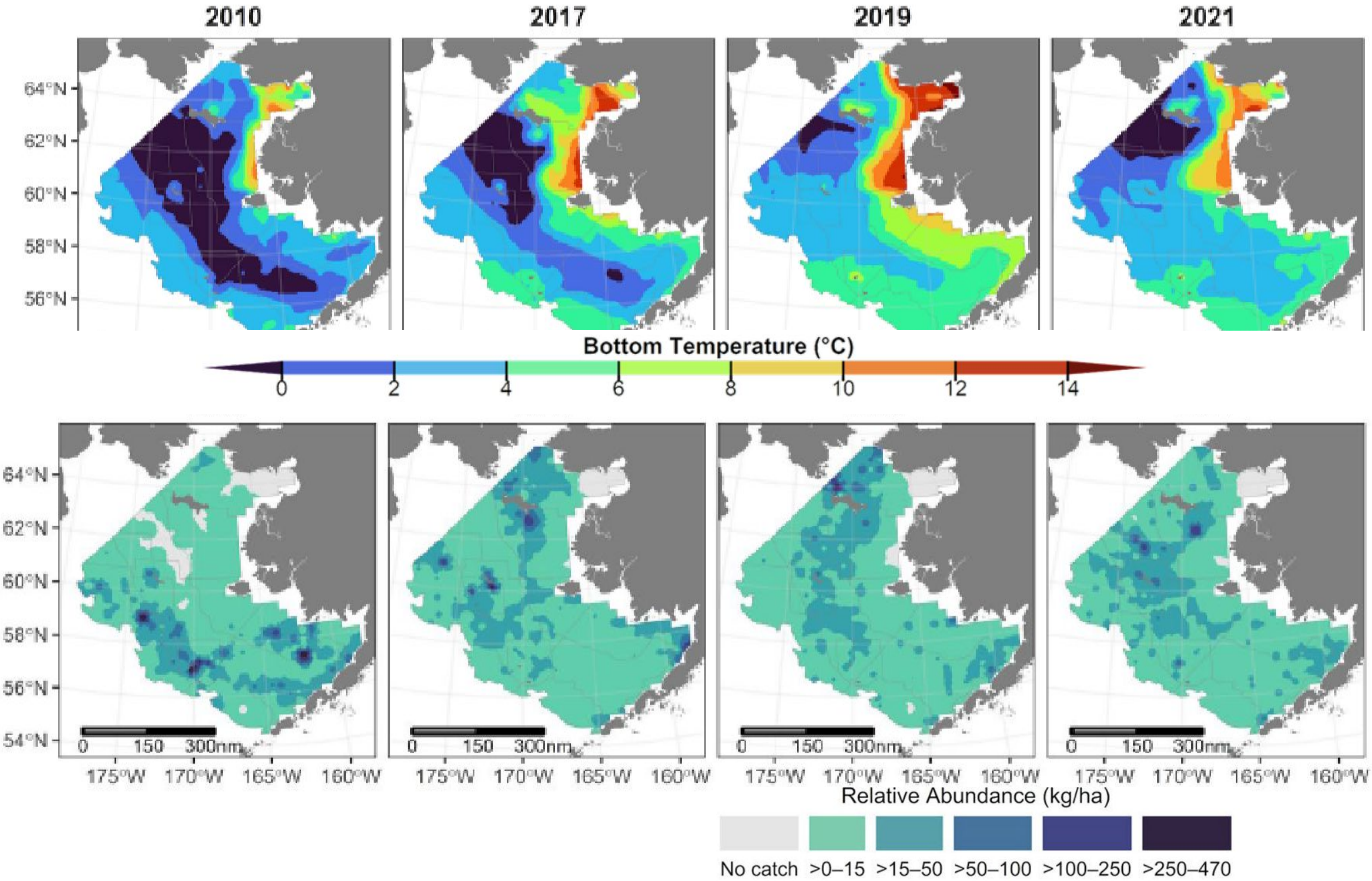
Bottom Temperature

Pacific cod Density

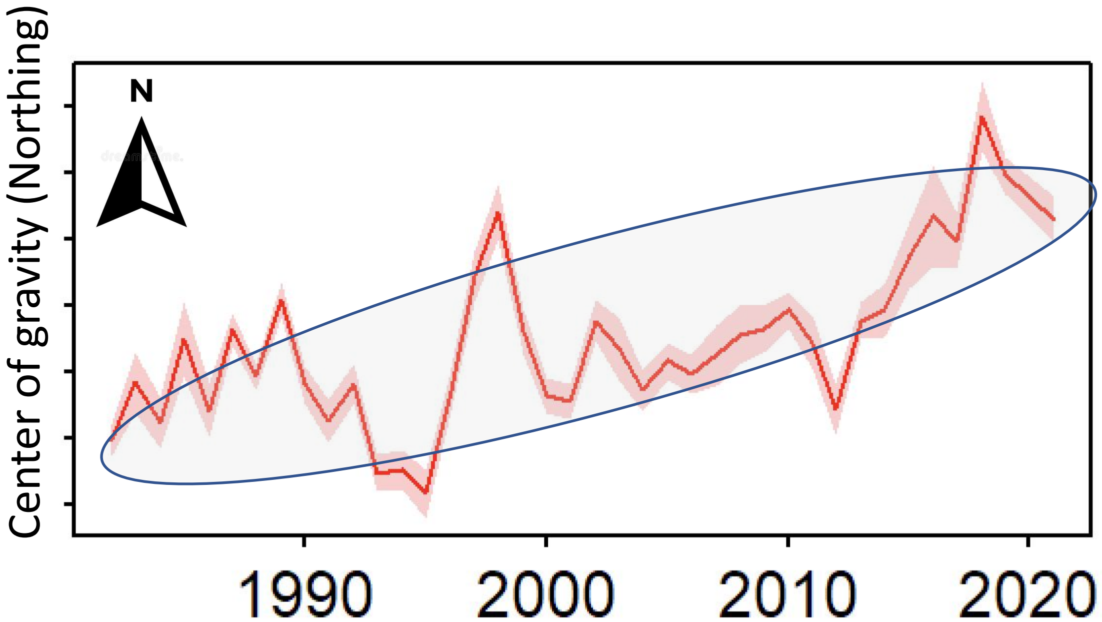


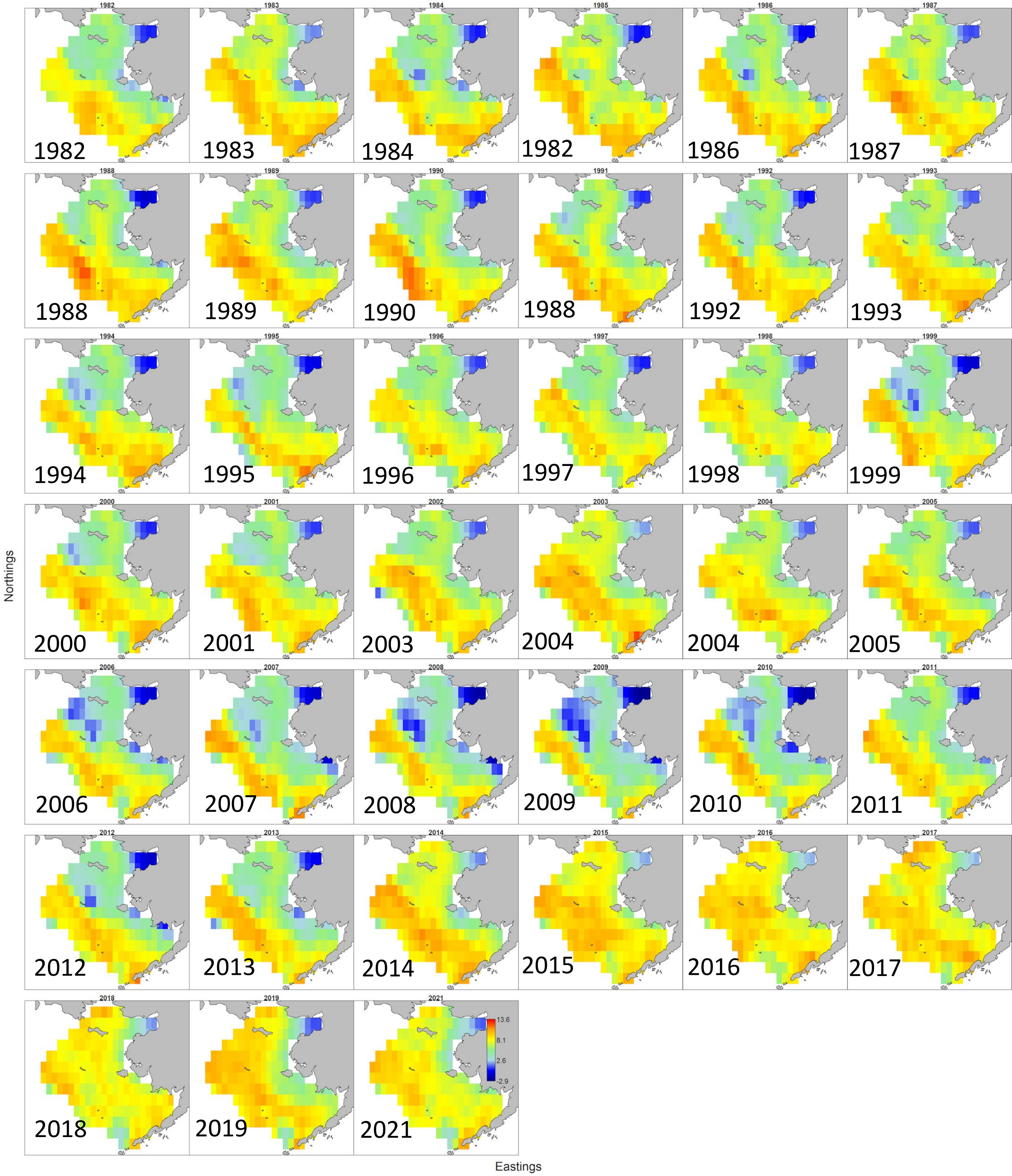
Pacific cod appear to be spatially structured by bottom temperature

to some degree…what about pollock?

Shifts in pollock distribution

- NMFS summer bottom trawl survey
- Fishery INDEPENDENT
- VAST model estimates





Shifts in pollock distribution

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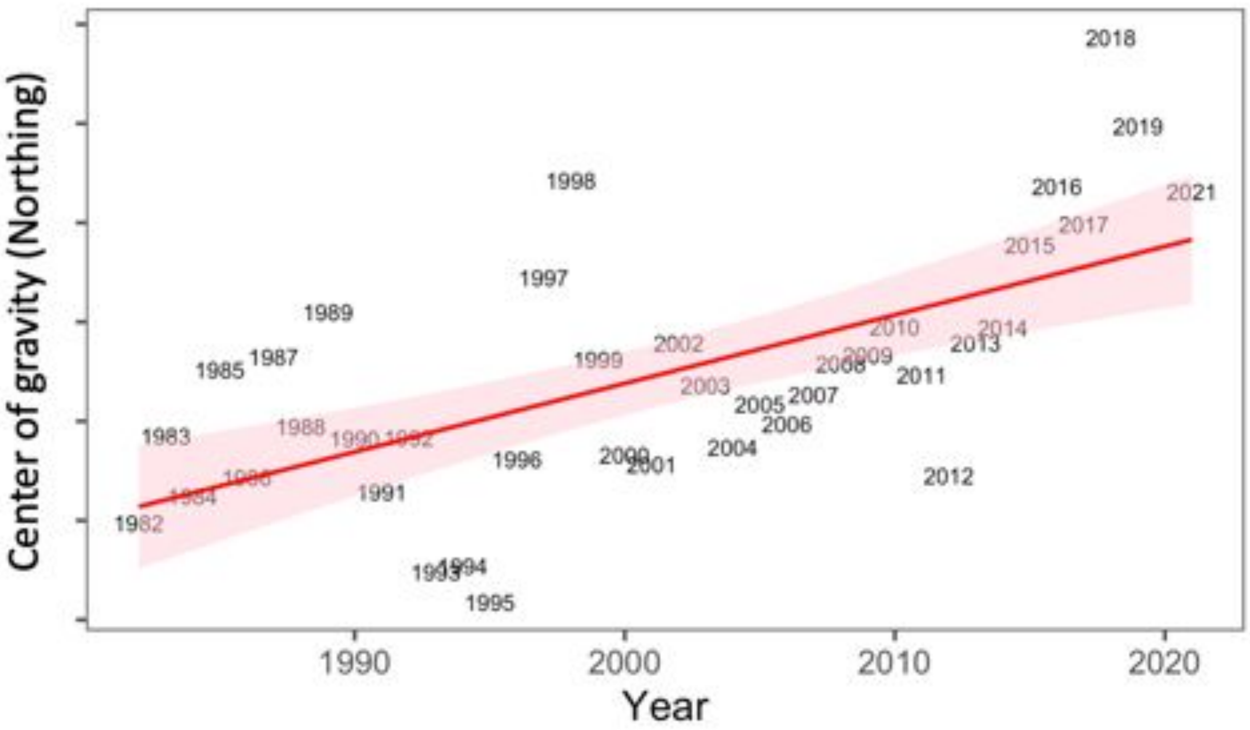

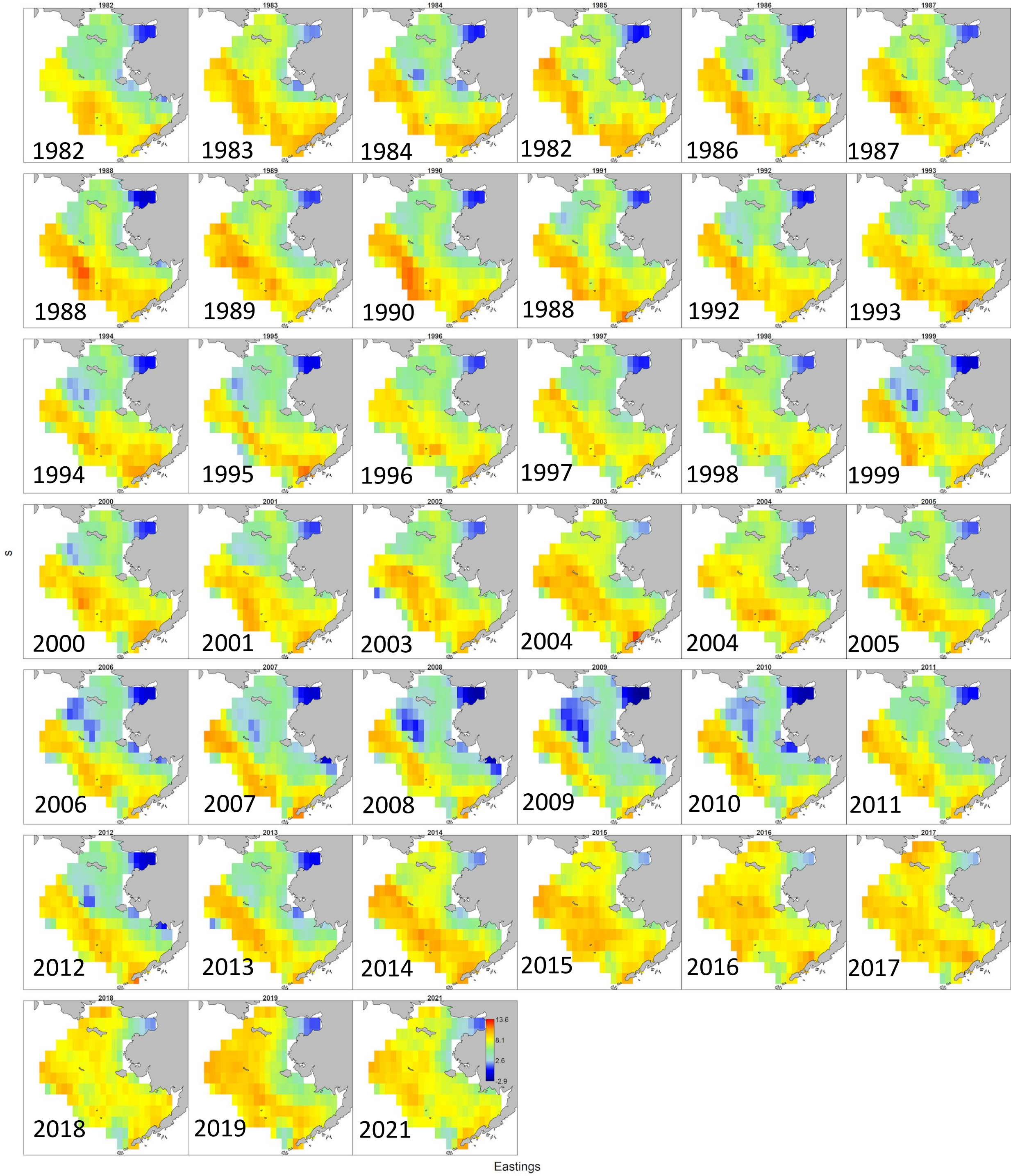

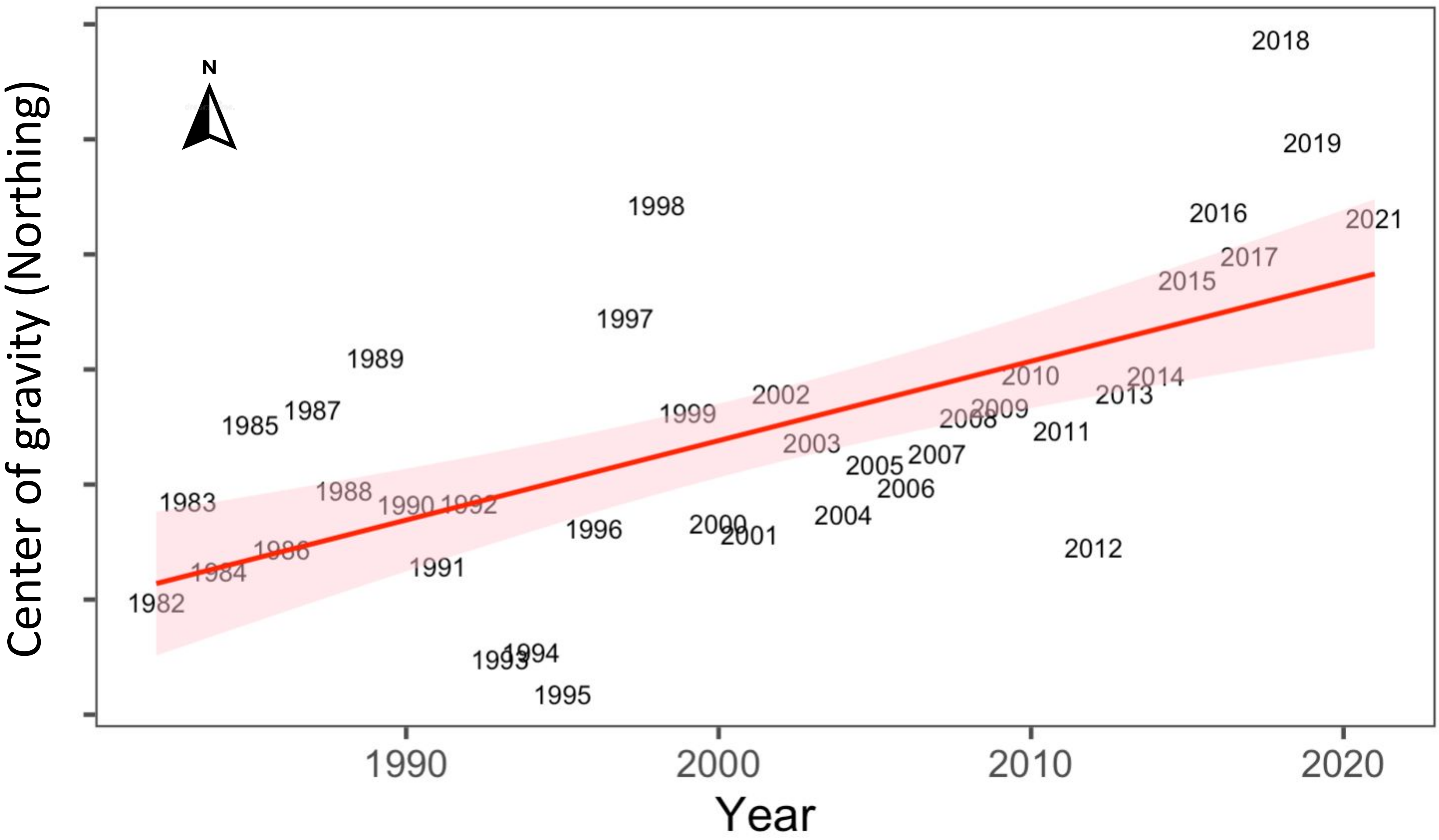

Center of gravity (Northing)
N
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
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1997
1998
1999
2000
2001
2002
2003
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2018
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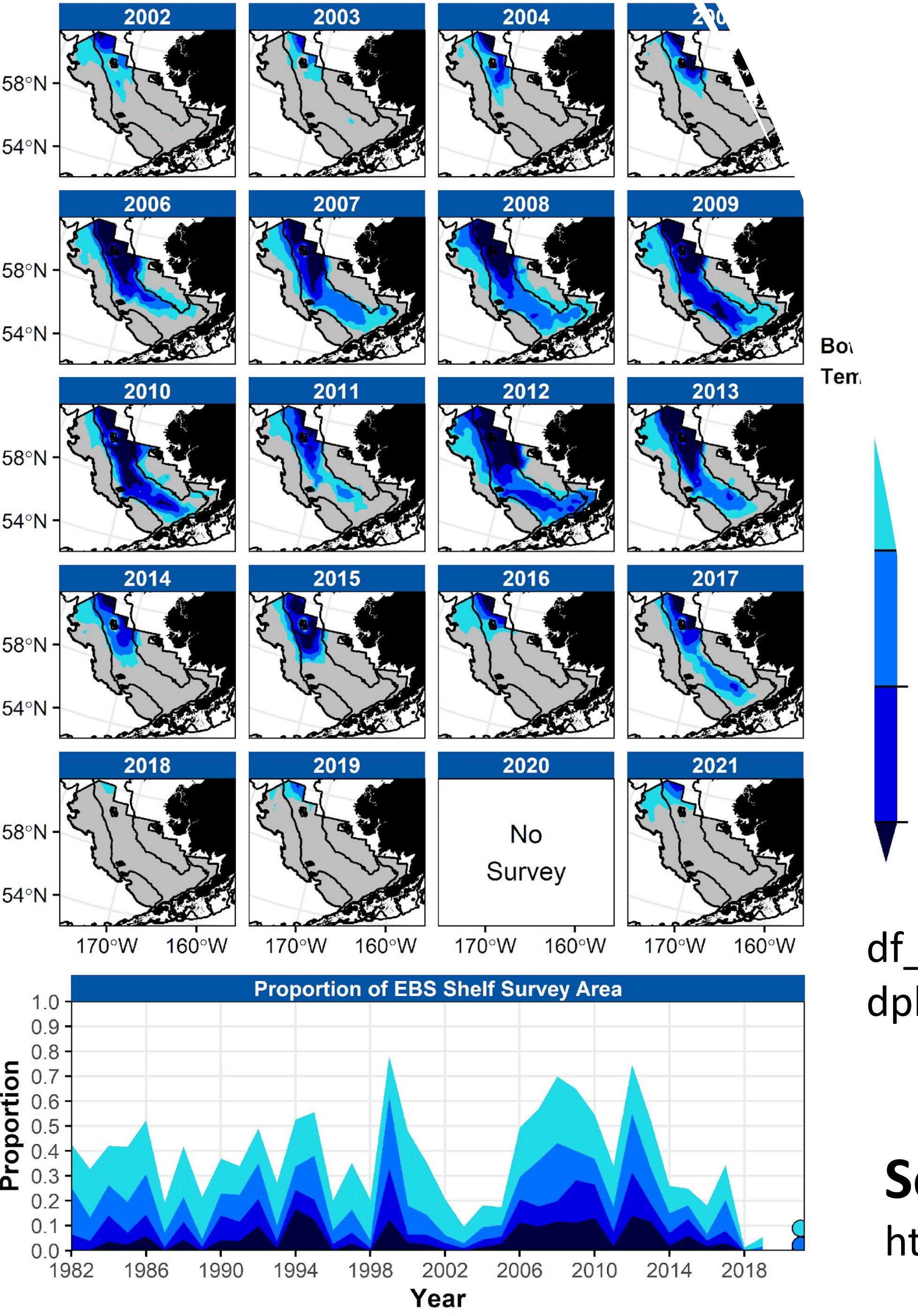
2021
1990
2000
2010
2020
Year

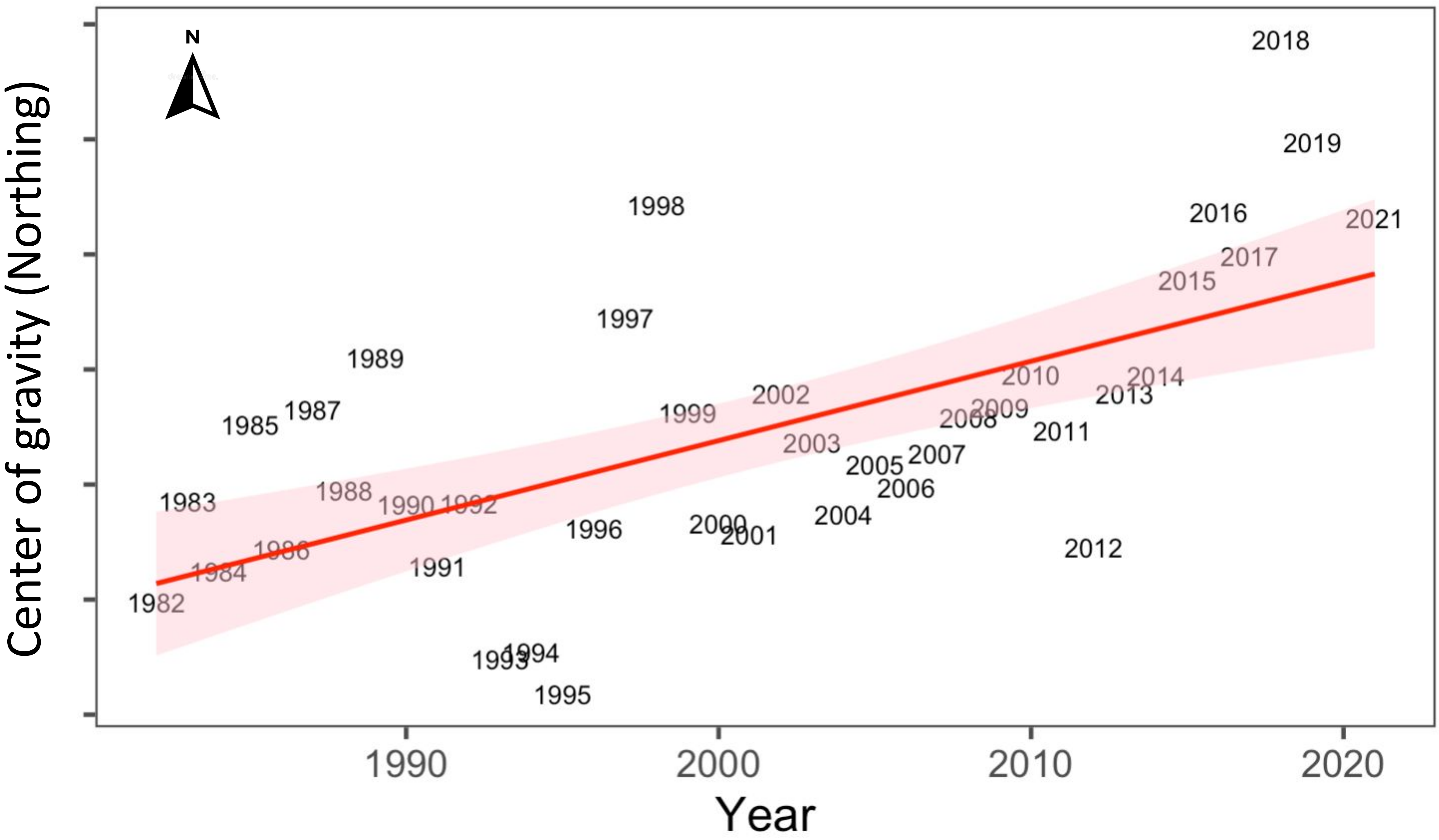


Another survey product: Bottom Temperature

```
df_cpe <- coldpool:::cold_pool_index |>
dplyr::select(year=YEAR,CPE=AREA_LTE2_KM2)
```

Sean Rohan and Lewis Barnett R package

https://github.com/afsc-gap-products/coldpool



Center of gravity (Northing)
N
2018
2019
1998
2016
2021
2017
2015
1997
1989
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2014
1987
2002
2013
1985
1999
2008
2009
2011
2003
2007
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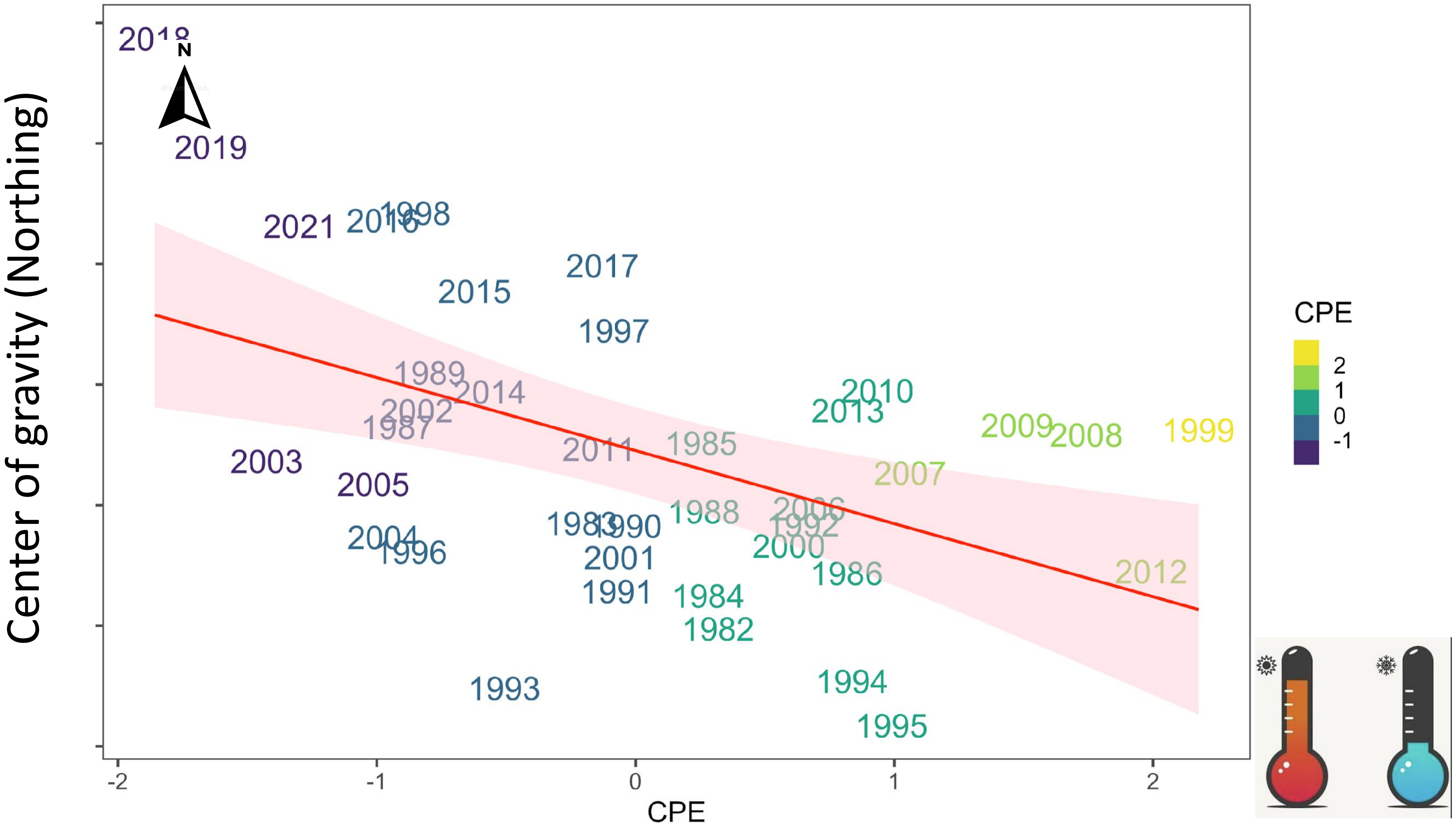
1994
1995
1990
2000
2010
2020
Year

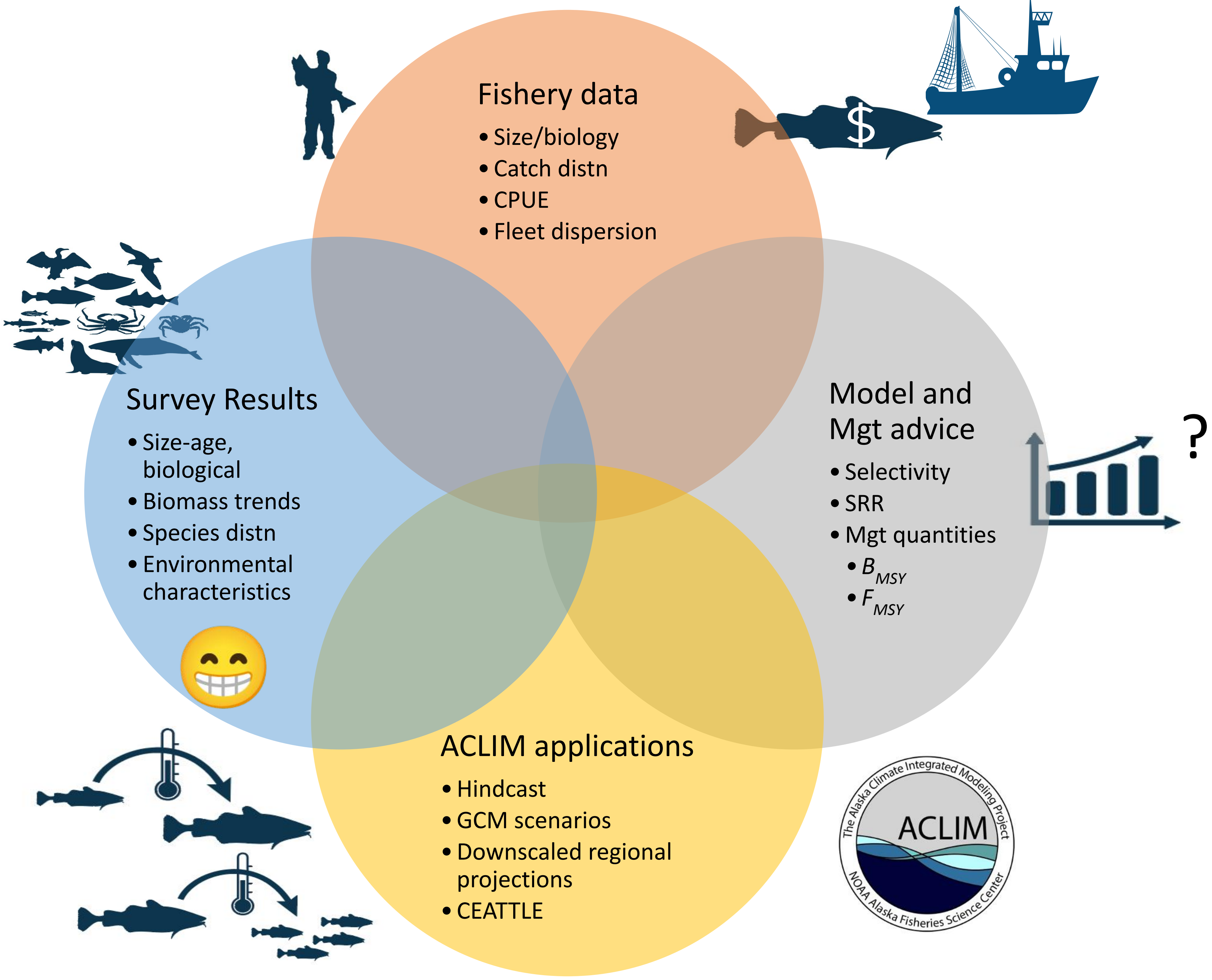


Center of gravity (Northing)
CPE
N
2019
2021
2016
1998
2017
2015
1997
1989
2014
2002
1987
2003
2005
2011
1985
2010
2013
2009
2008
1999
2007
1988
2006
1992
2000
1983
1990
2004
1996
2001
1986
2012
1991
1984
1982
1993
1994
1995
-2
-1
0
1
2

Yes, groundfish distribution appears to be affected by temperature

at least for pollock and cod

And driver likely the cold-pool extent (CPE)



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• CEATTLE
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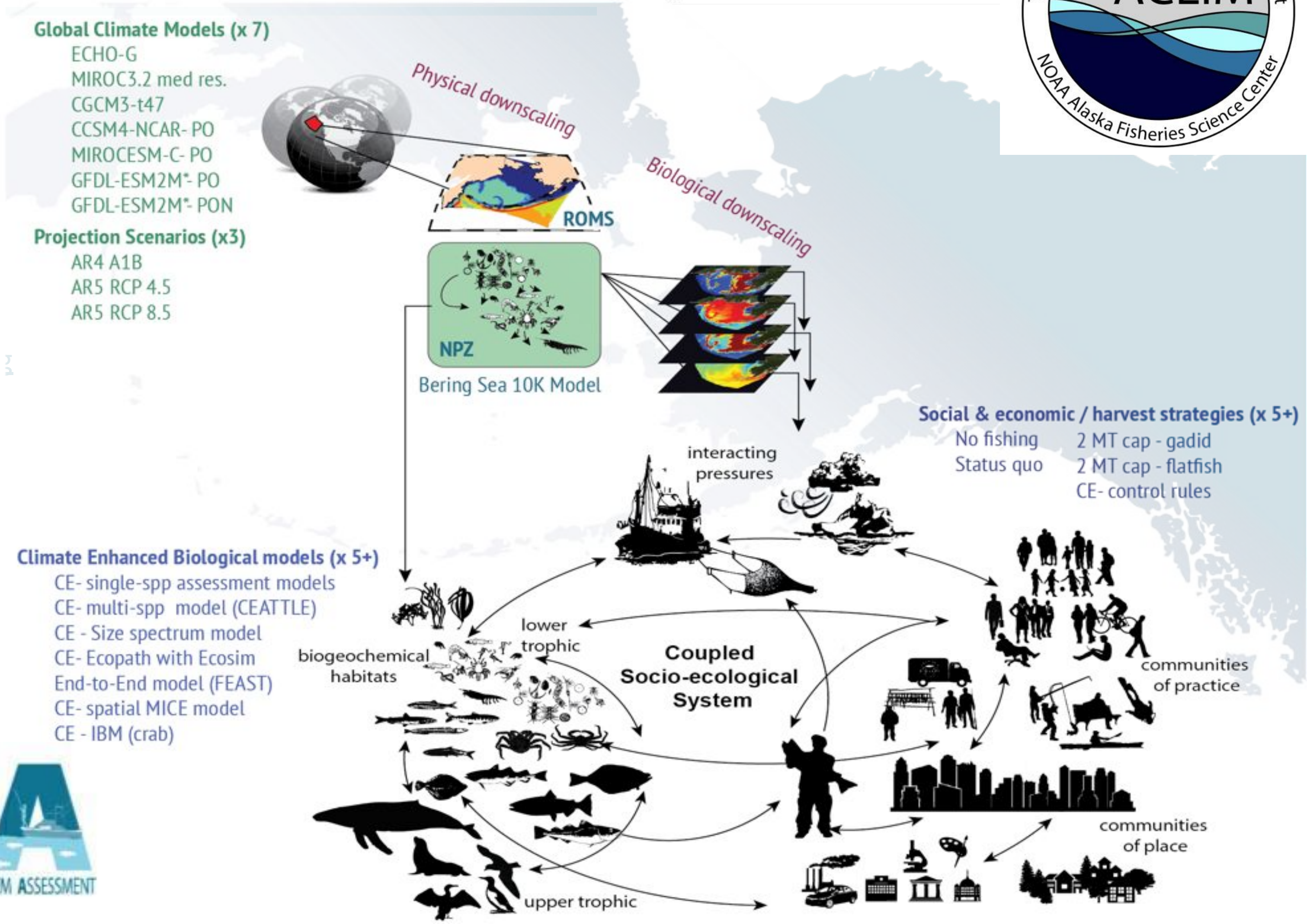
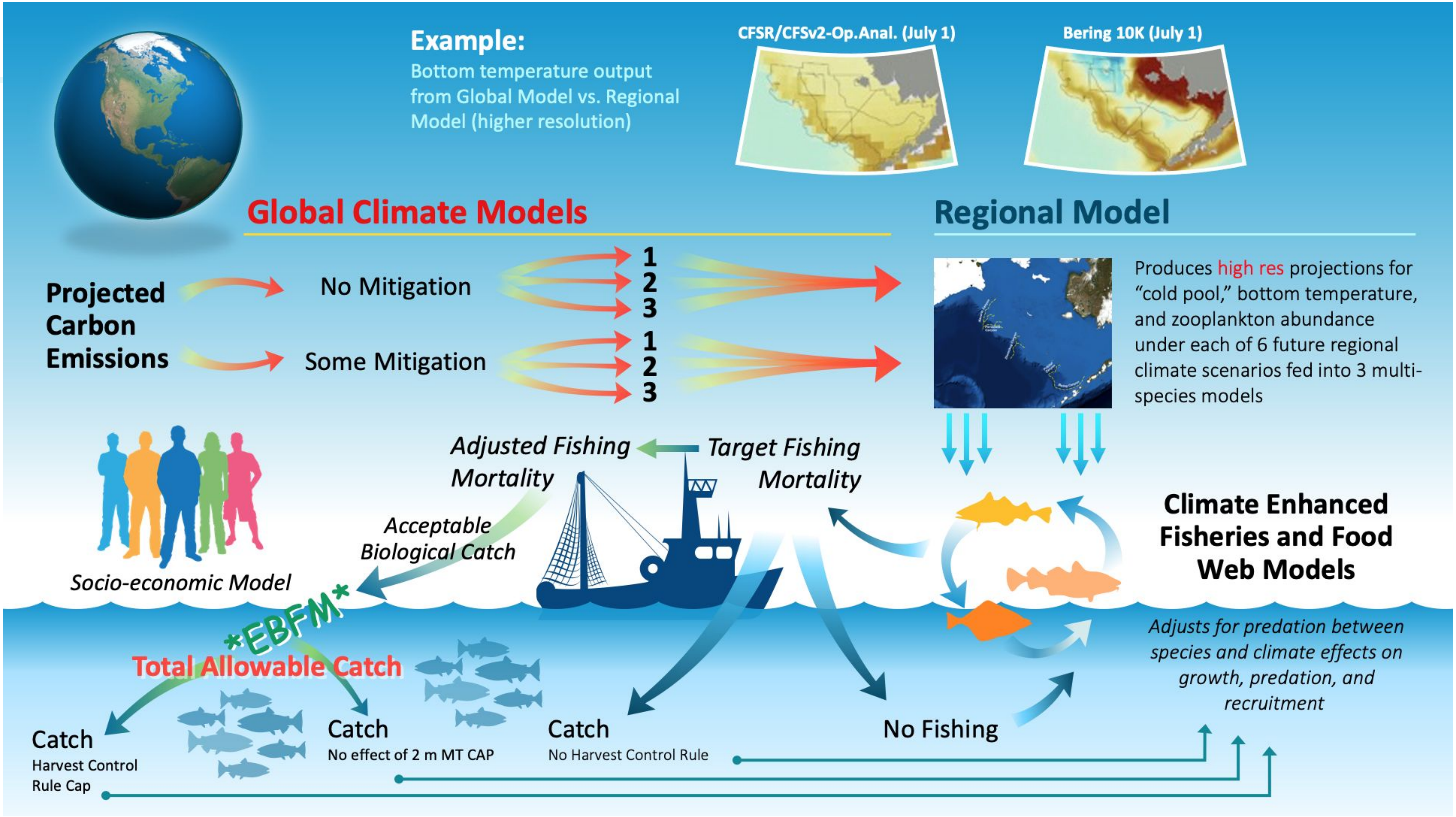
What is the Alaska Climate Integrated Modeling Project?

Operational suite of coupled socio-ecological models fc
climate fisheries hindcasts, forecasts, projections and
Management Strategy Evaluation



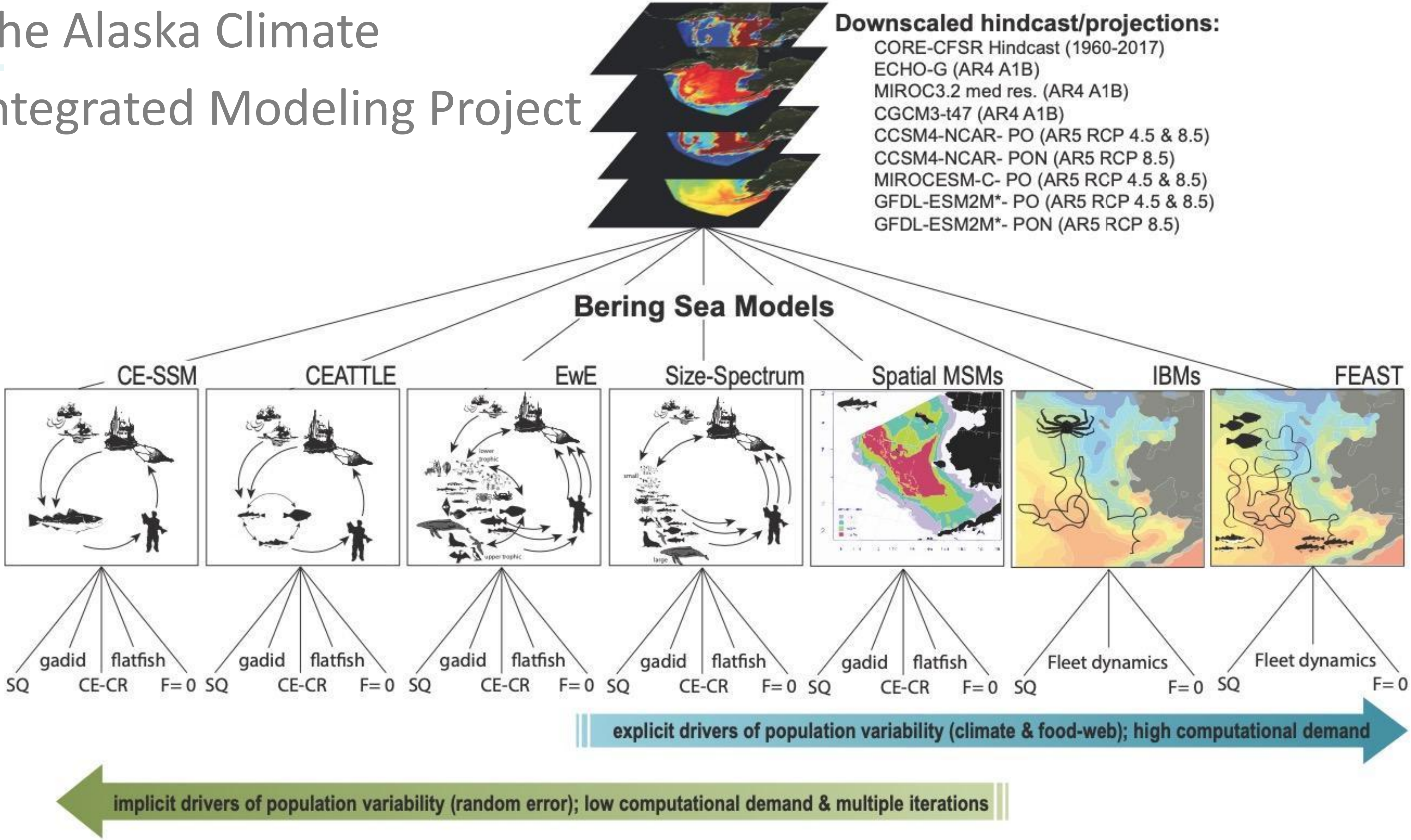
[www.fisheries.noaa.gov/alaska/ecosystems/alaska-climate-int
rated-modeling-project](www.fisheries.noaa.gov/alaska/ecosystems/alaska-climate-integrated-modeling-project)

Hollowed et al. 2020. Frontiers in Mar. Sci. doi: 10.3389/fmars.2019.00775



Example:
Bottom temperature output from Global Model vs. Regional Model (higher resolution)
CFSR/CFSv2-Op.Anal. (July 1)
Bering 10K (July 1)
Global Climate Models
Regional Model
Projected Carbon Emissions
No Mitigation
Some Mitigation
1
2
3
1
2
3
Produces high res projections for "cold pool," bottom temperature, and zooplankton abundance under each of 6 future regional climate scenarios fed into 3 multi-species models
Adjusted Fishing Mortality
Target Fishing Mortality
Acceptable Biological Catch
Socio-economic Model
EBFM
Climate Enhanced Fisheries and Food Web Models
Adjusts for predation between species and climate effects on growth, predation, and recruitment
Total Allowable Catch
Catch
Harvest Control Rule Cap
Catch
No effect of 2 m MT CAP
Catch
No Harvest Control Rule
No Fishing

The Alaska Climate Integrated Modeling Project



Climate scenarios

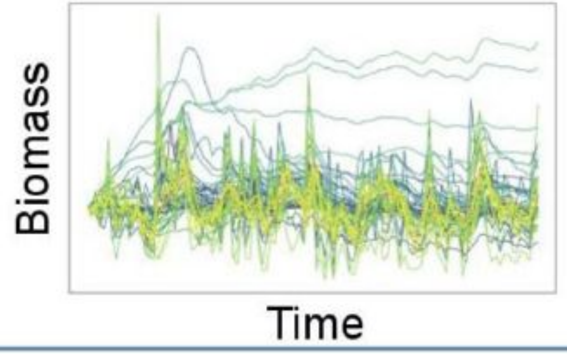
RCP 4.5 RCP 8.5

Earth system models

CESM GFDL MIROC

Regional ocean and biogeochemical model

Food web model



Fisheries scenarios

1. Status quo
2. Gadid preference
3. Flatfish preference
4. No Fishing

Whitehouse et al. 2021

Front. Mar. Sci., 03 February 2021
Sec. Marine Fisheries, Aquaculture and Living Resources
https://doi.org/10.3389/fmars.2021.624301

This article is part of the Research Topic
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George A. Whitehouse[1,2,3*], Kerim Y. Aydin[2], Anne B. Hollowed[2], Kirstin K. Holsman[2], Wei Cheng[1,4], Amanda Faig[3], Alan C. Haynie[2], Albert J. Hermann[1,4], Kelly A. Kearney[1,2], André E. Punt[3] and Timothy E. Essington[3]

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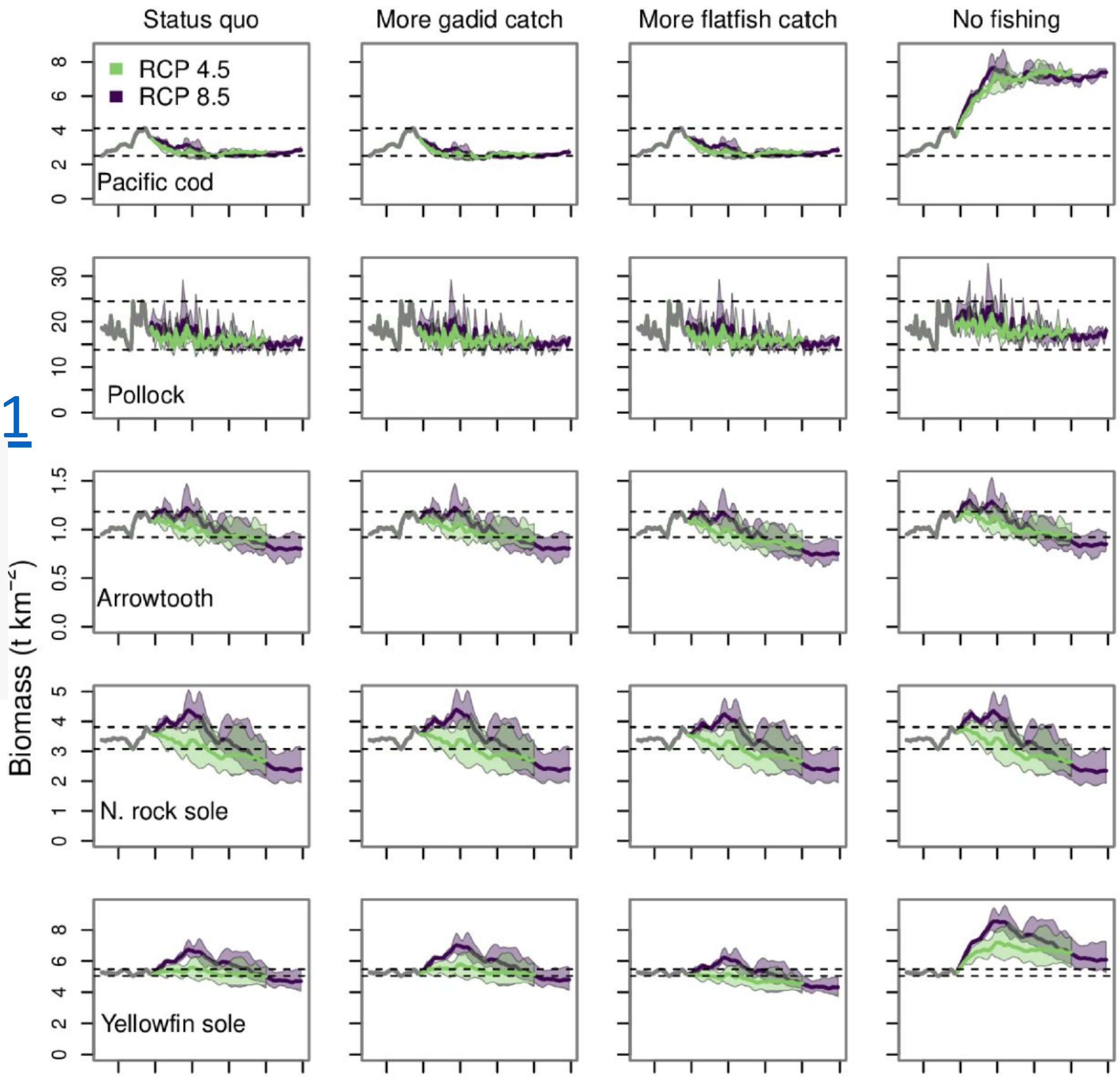
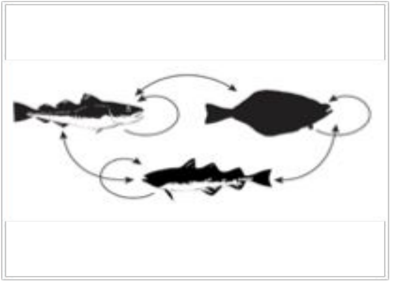
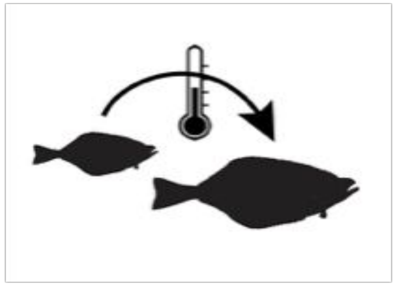
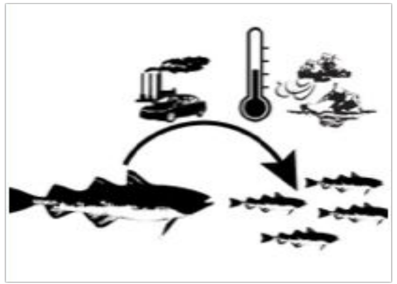


CEATTLE (Eastern Bering Sea)

Kirstin Holsman

Mortality	Weight @ Age	Rec	HCRs
			
• Empirical diets • Bioenergetics	• Empirical • VonB with Temp	• Climate-S/R • S/R • mean R	• Climate ABC • MMSY • MEY • SPR • Aggregate MSY

- Operational advice
  - Appendix to BSAI pollock assessment (2016 to now)
  - M2 index for EBS ecosystem status report (2016 to now)
  - M2 index for ESP (2020 to now)
- Research
  - ACLIM - climate MSE
  - Lenfest NFS
  - Lenfest ocean wealth

2021 Climate-enhanced multi-species Stock Assessment for walleye pollock, Pacific cod, and arrowtooth flounder in the South Eastern Bering Sea

Kirstin K. Holsman, Jim Ianelli, Kerim Aydin, Grant Adams, Kelly Kearney, Kalei Shotwell, Grant Thompson, and Ingrid Spies

kirstin.holsman@noaa.gov *November 2021*
Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA, 7600 Sand Point Way N.E., Seattle, Washington 98115

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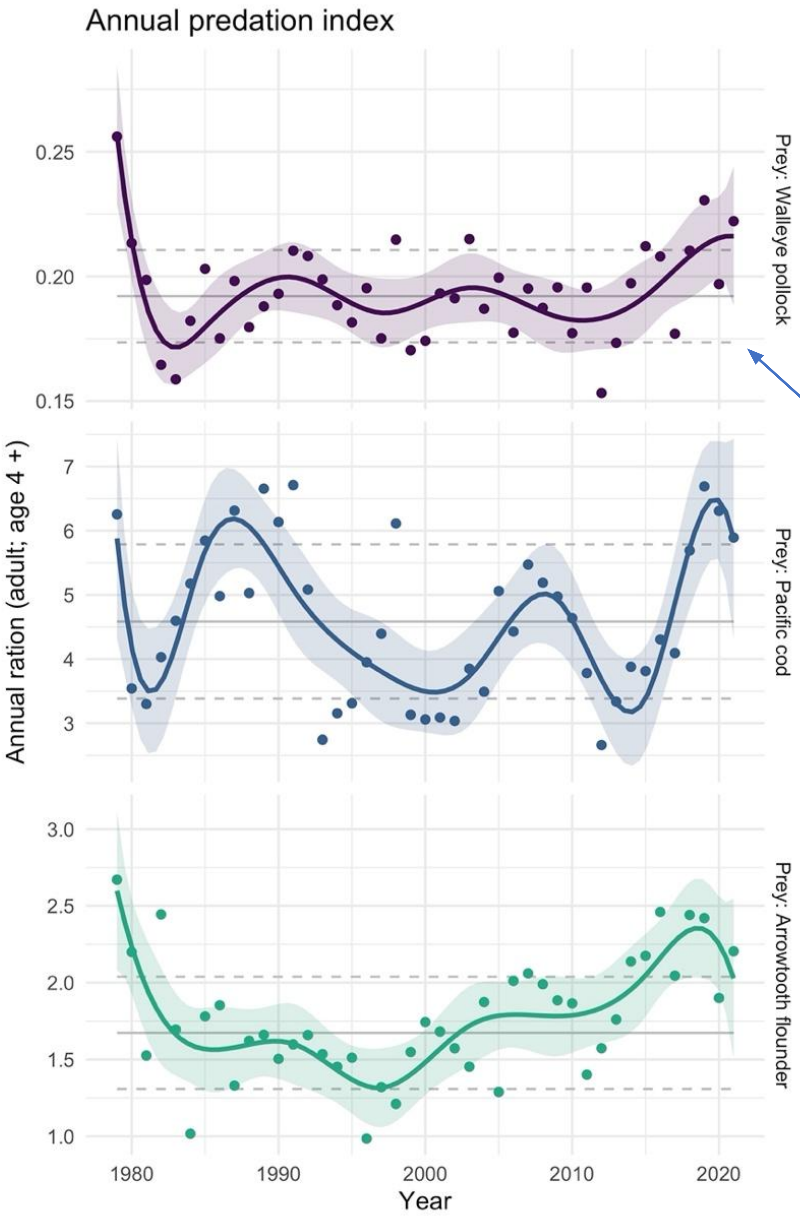
Increase in energetic demand (ration)

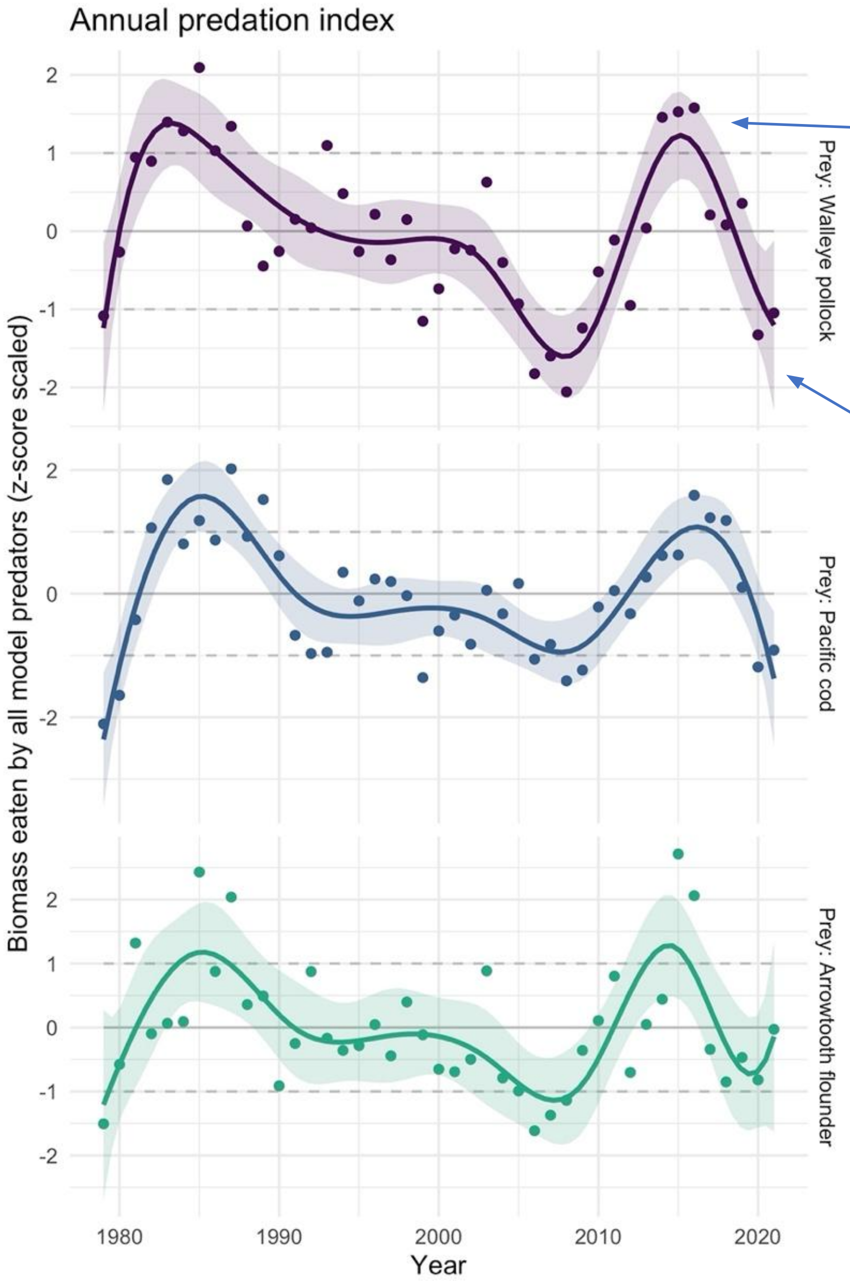
Kirstin Holsman

Kg/yr



Warm temp
increases in individual ration

Declines in predation index

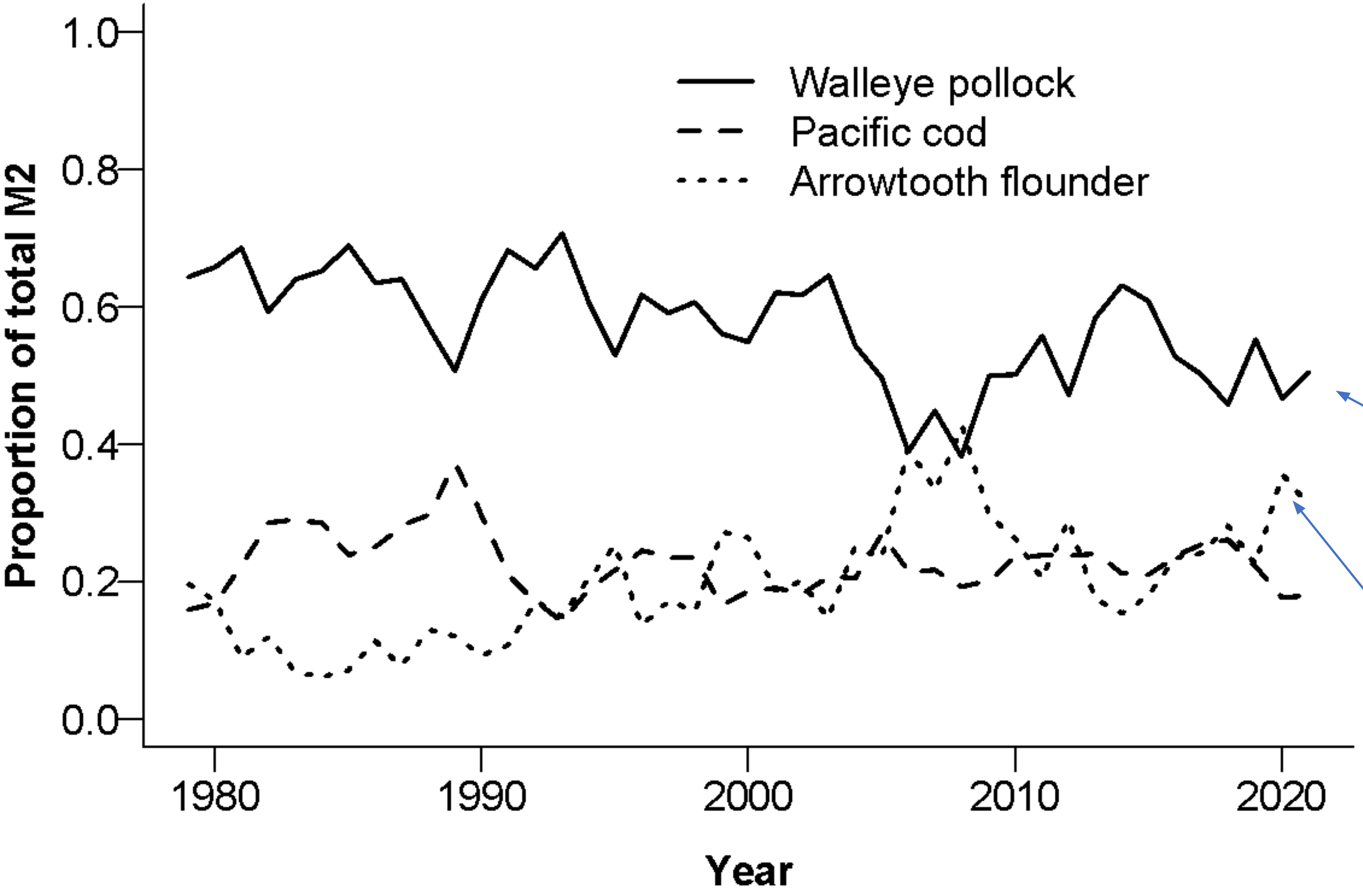


Warm temp + high predator biomass = high predation

Warm temp + low predator biomass = lower predation

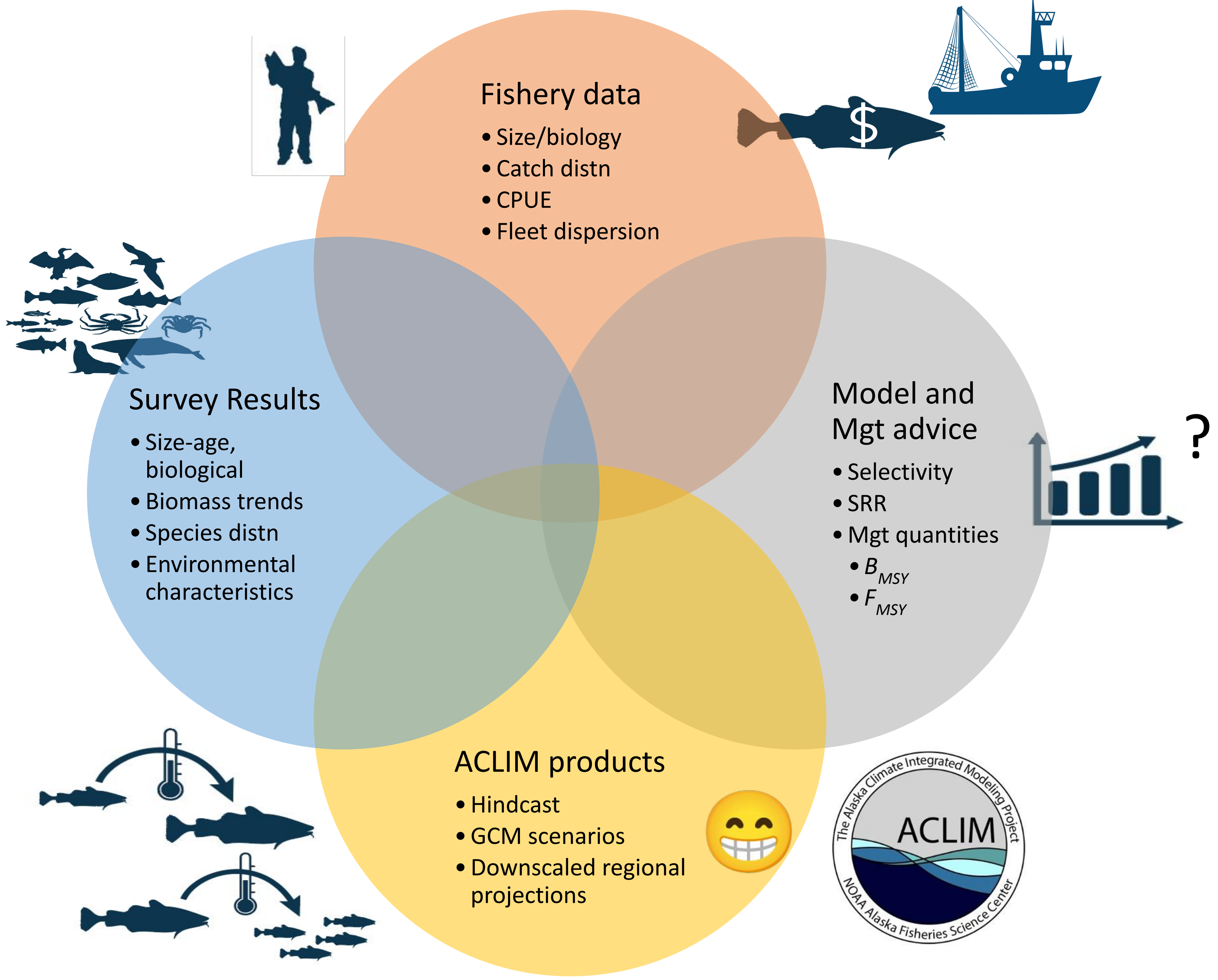
Kirstin Holsman

Pollock Predation Mortality



Cannibalism

Arrowtooth predation on pollock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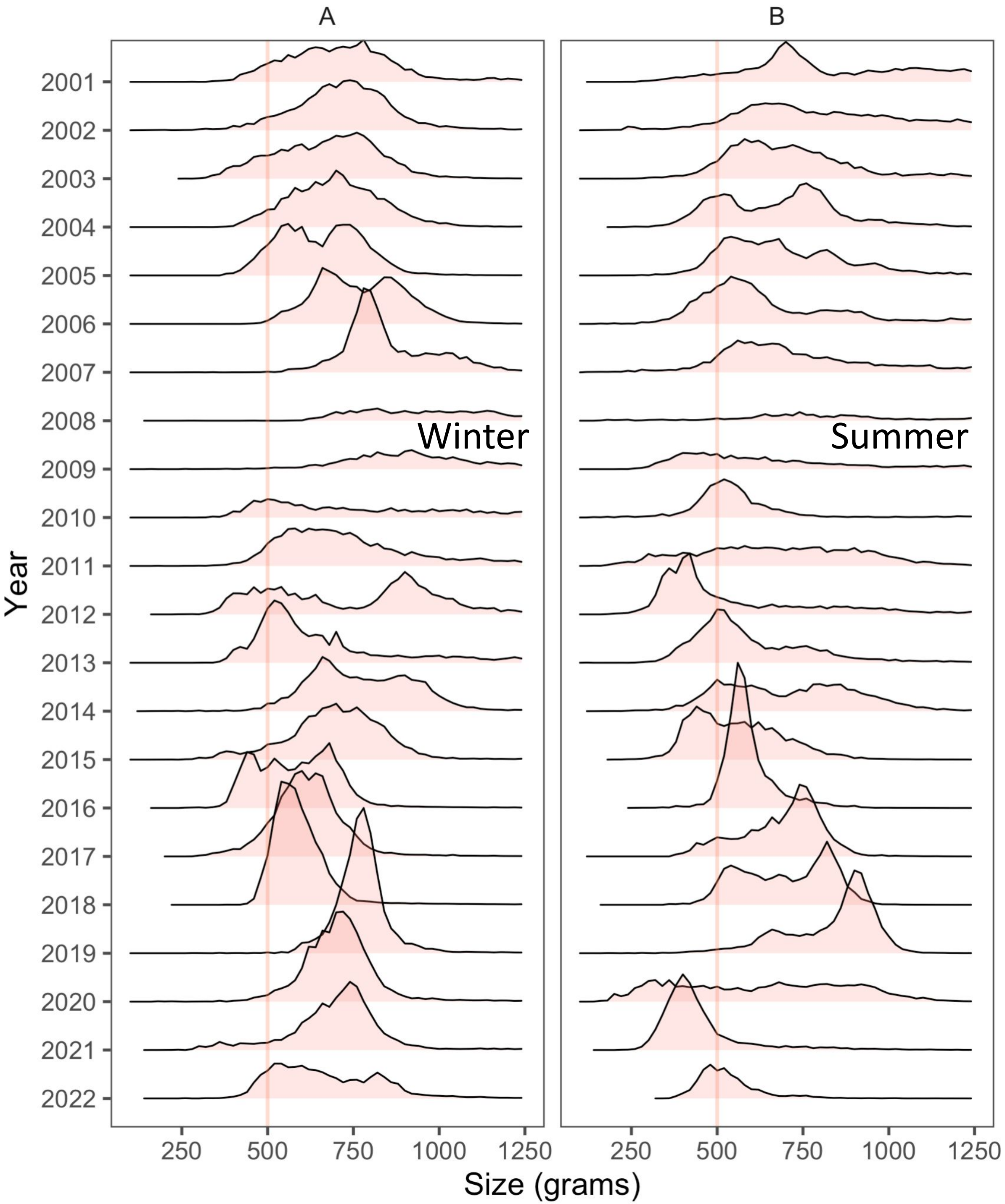
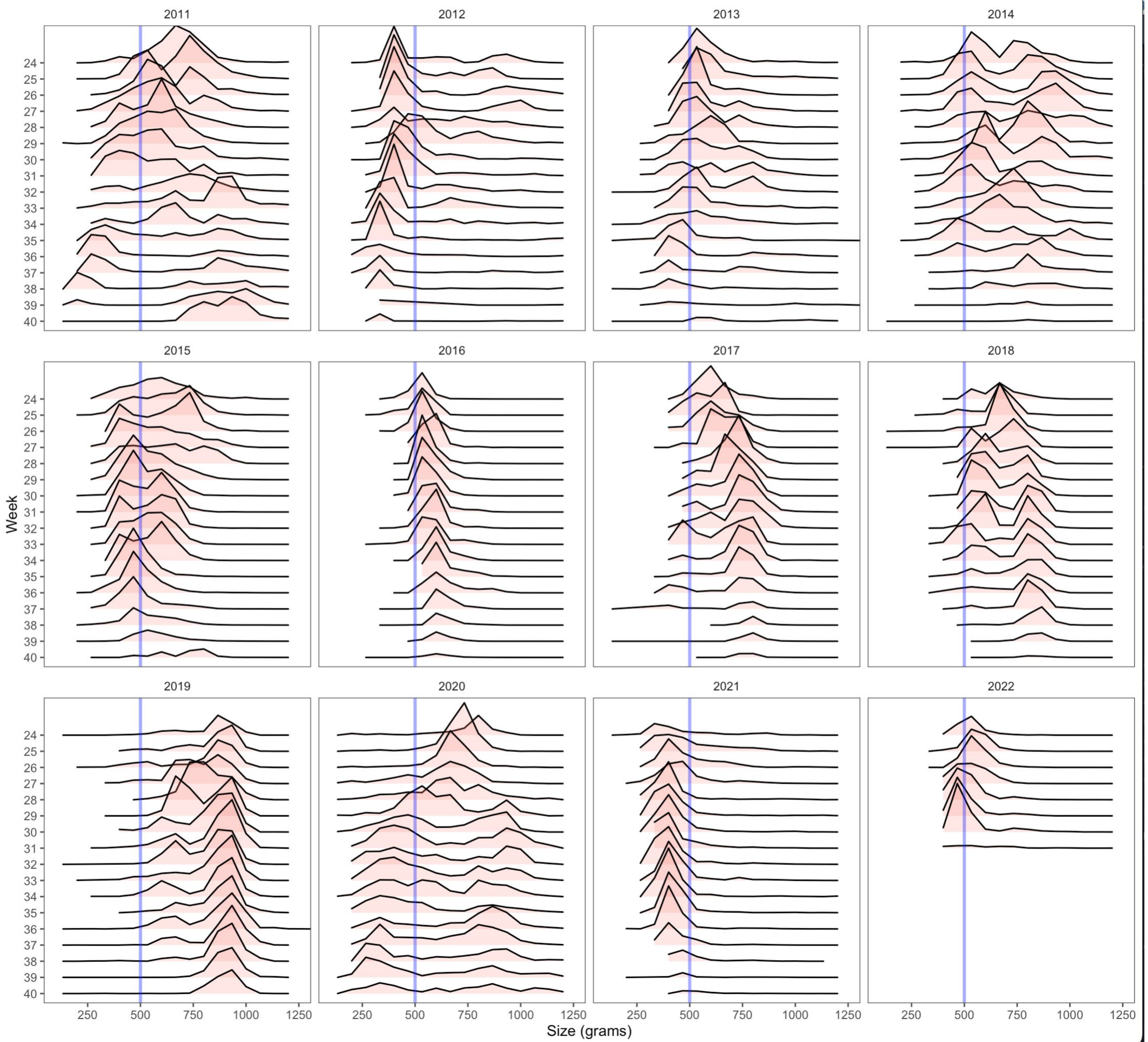
Bering Sea Pollock Fishing conditions

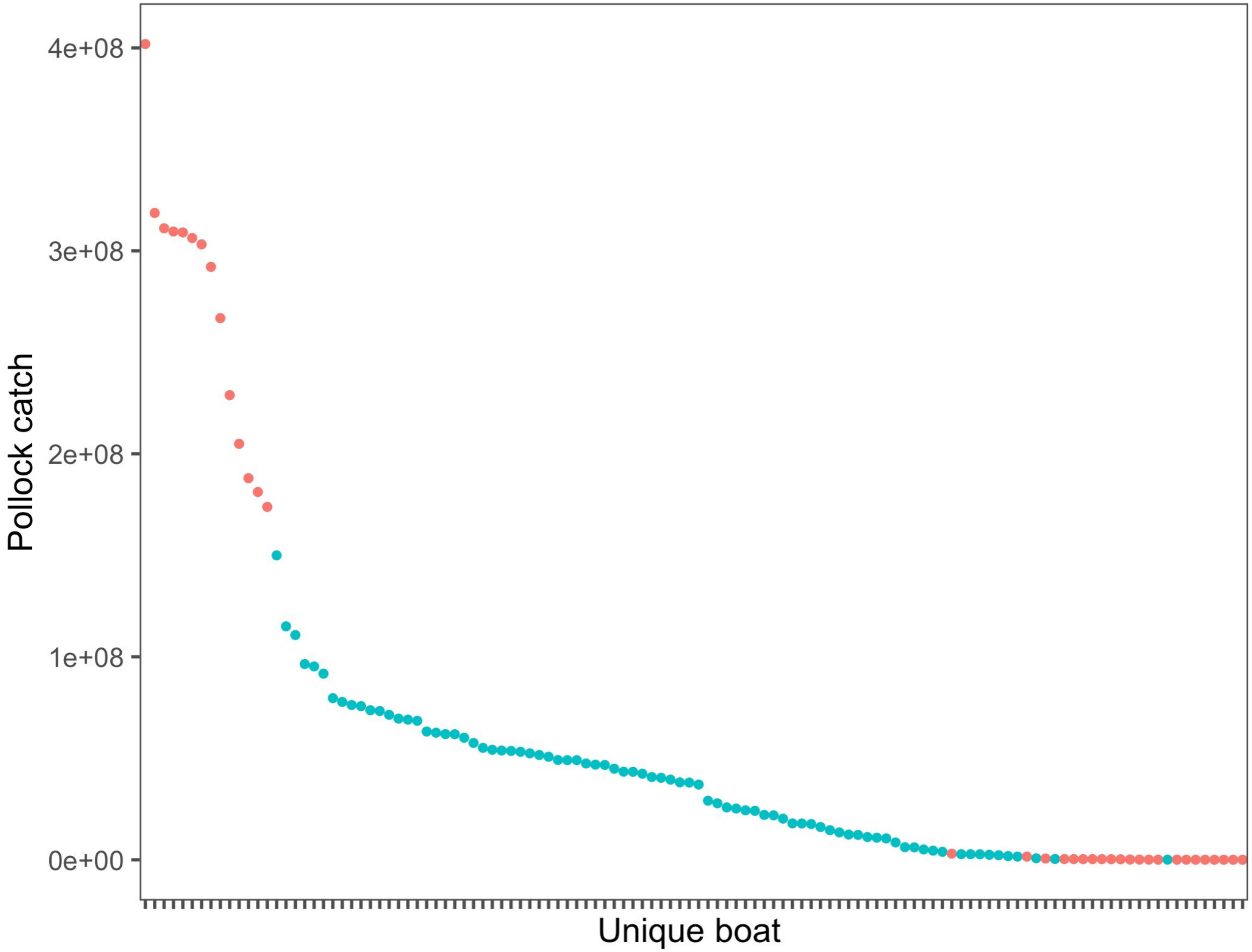
Trends in weight frequency of catch



B-season

Tow-by-tow mean weight frequency by week

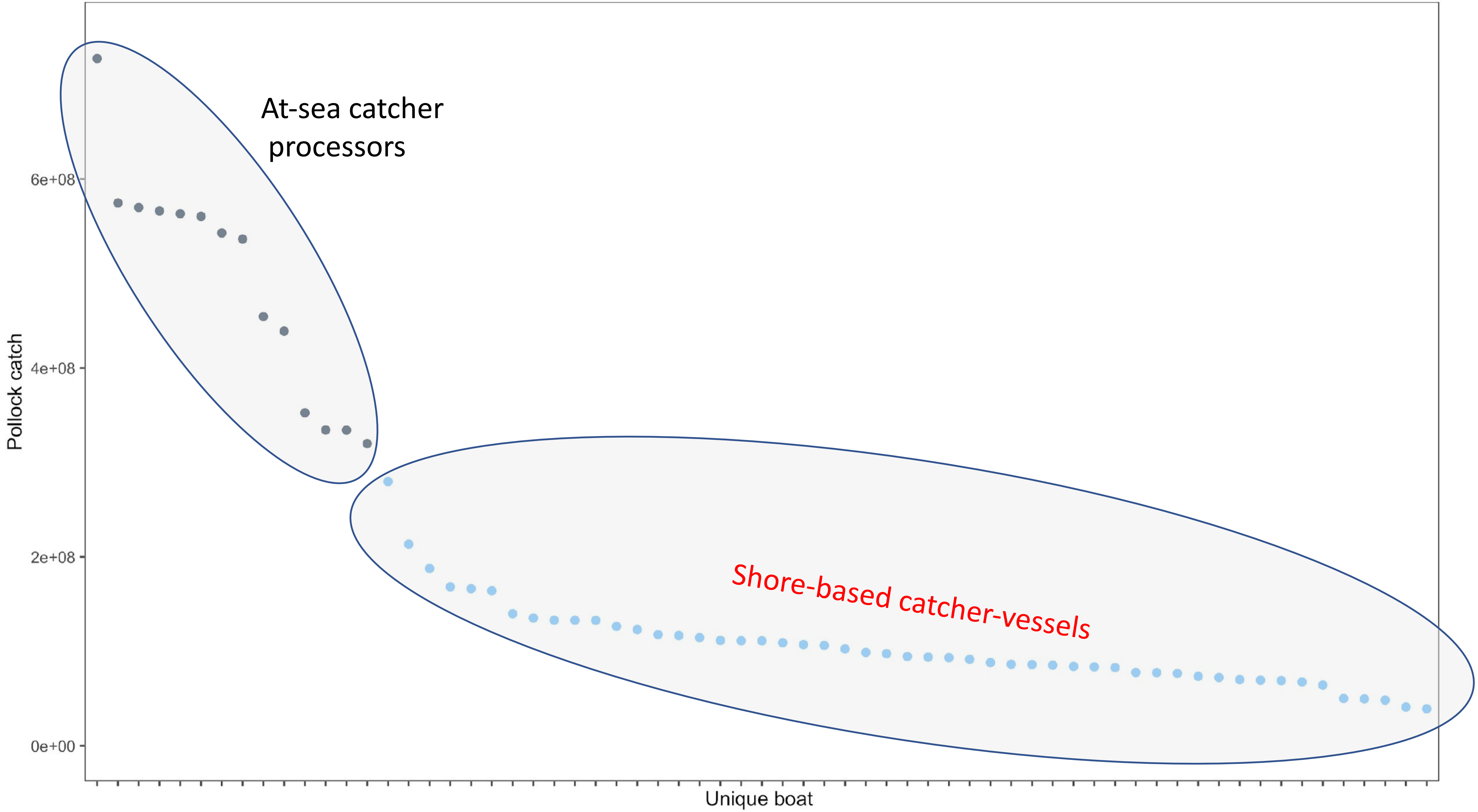




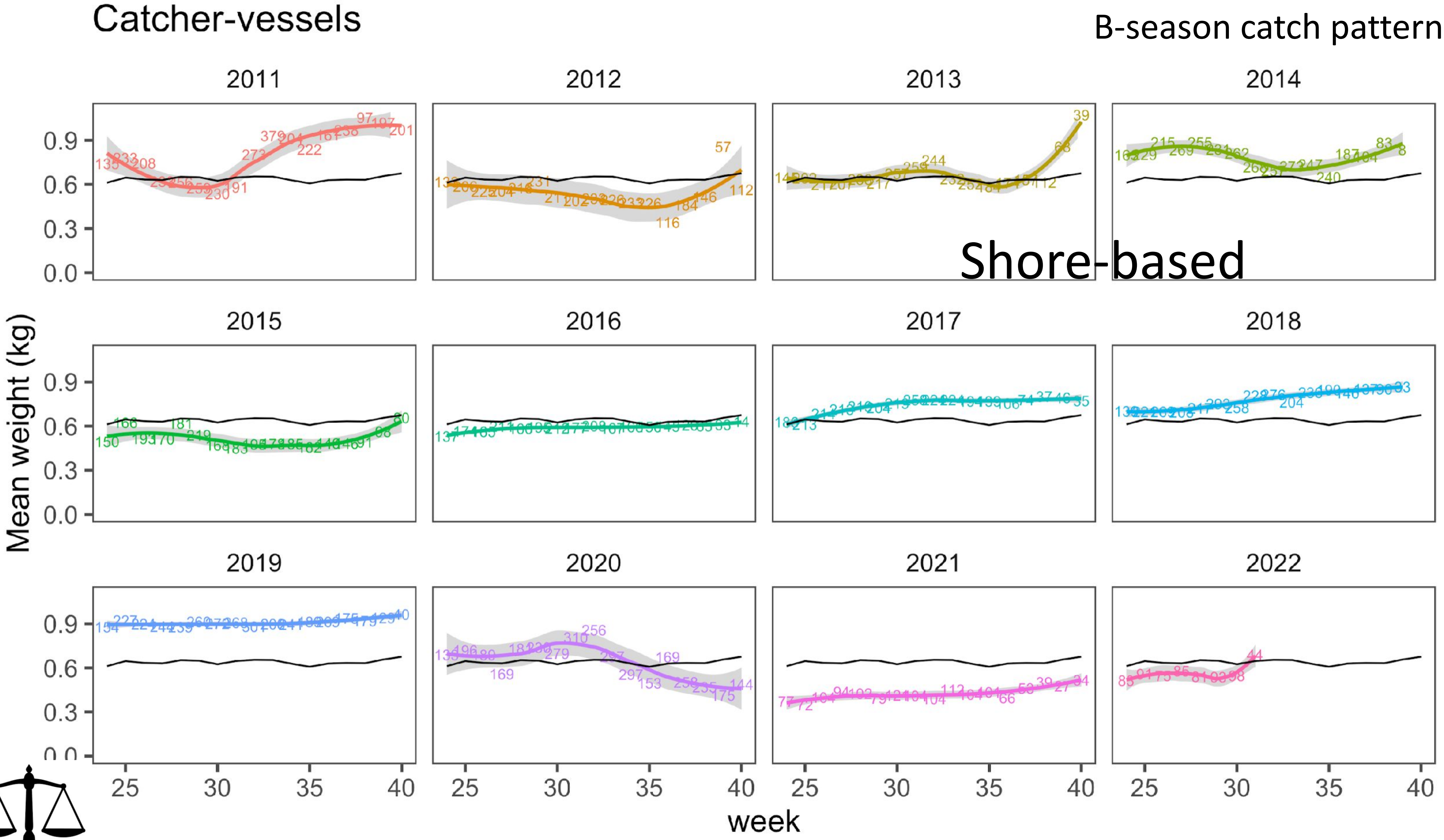
B-season catch patterns

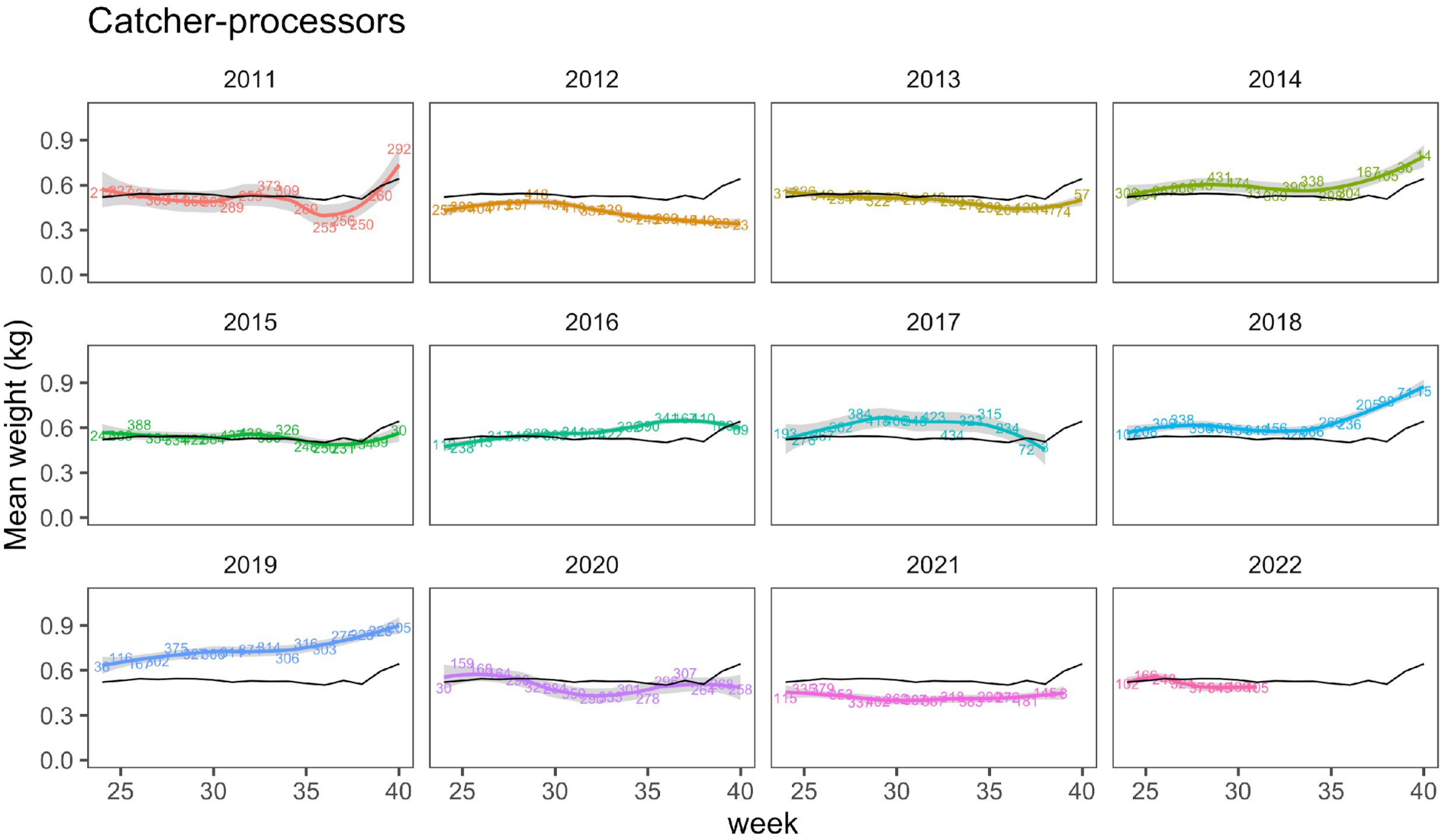
Deeper dive into
observer data

B-season catch patterns



B-season catch patterns



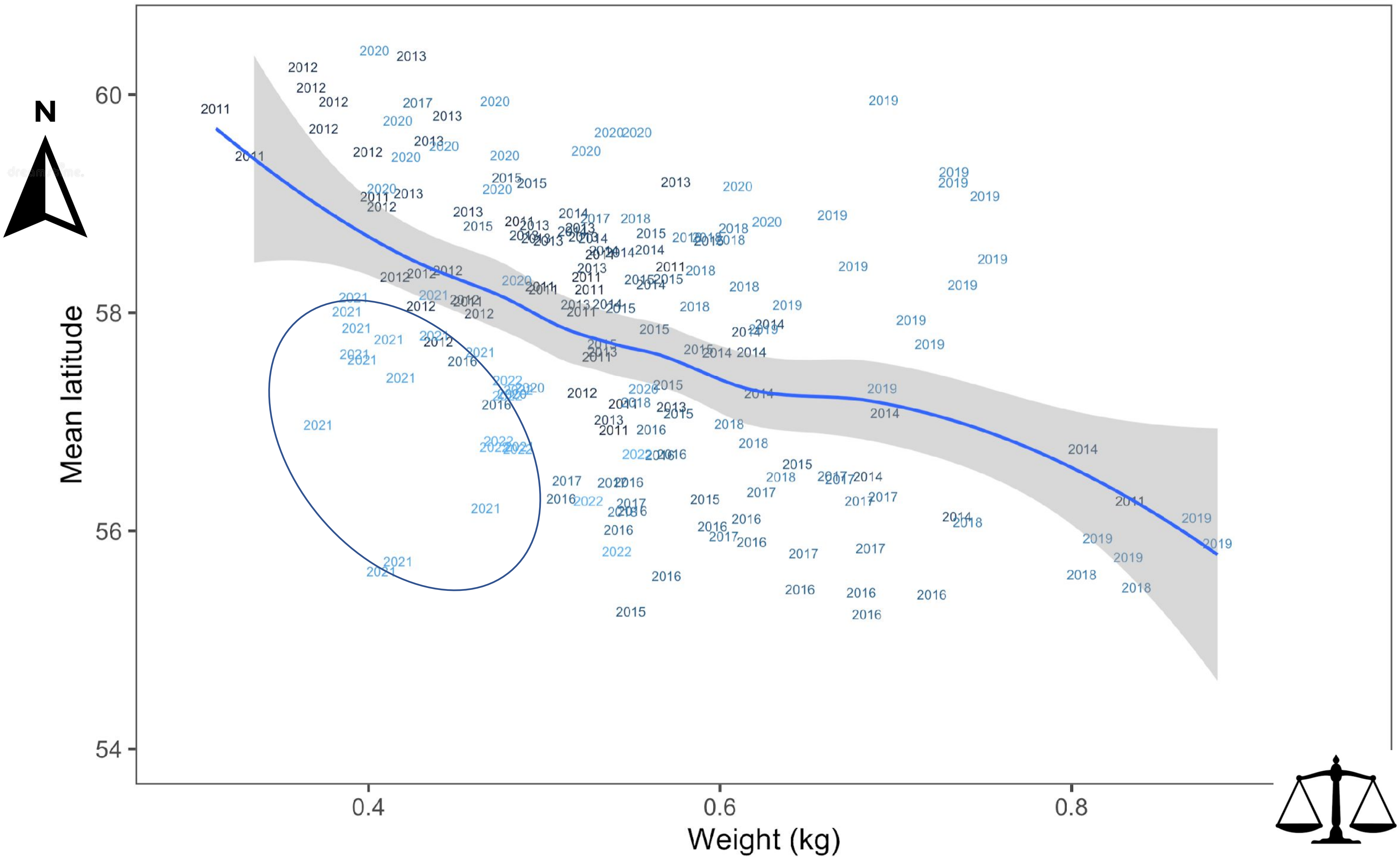


Catcher-processors
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
Mean weight (kg)
0.0
0.3
0.6
0.9
25
30
35
40
week

How much is due to shifted pattern of fishing?

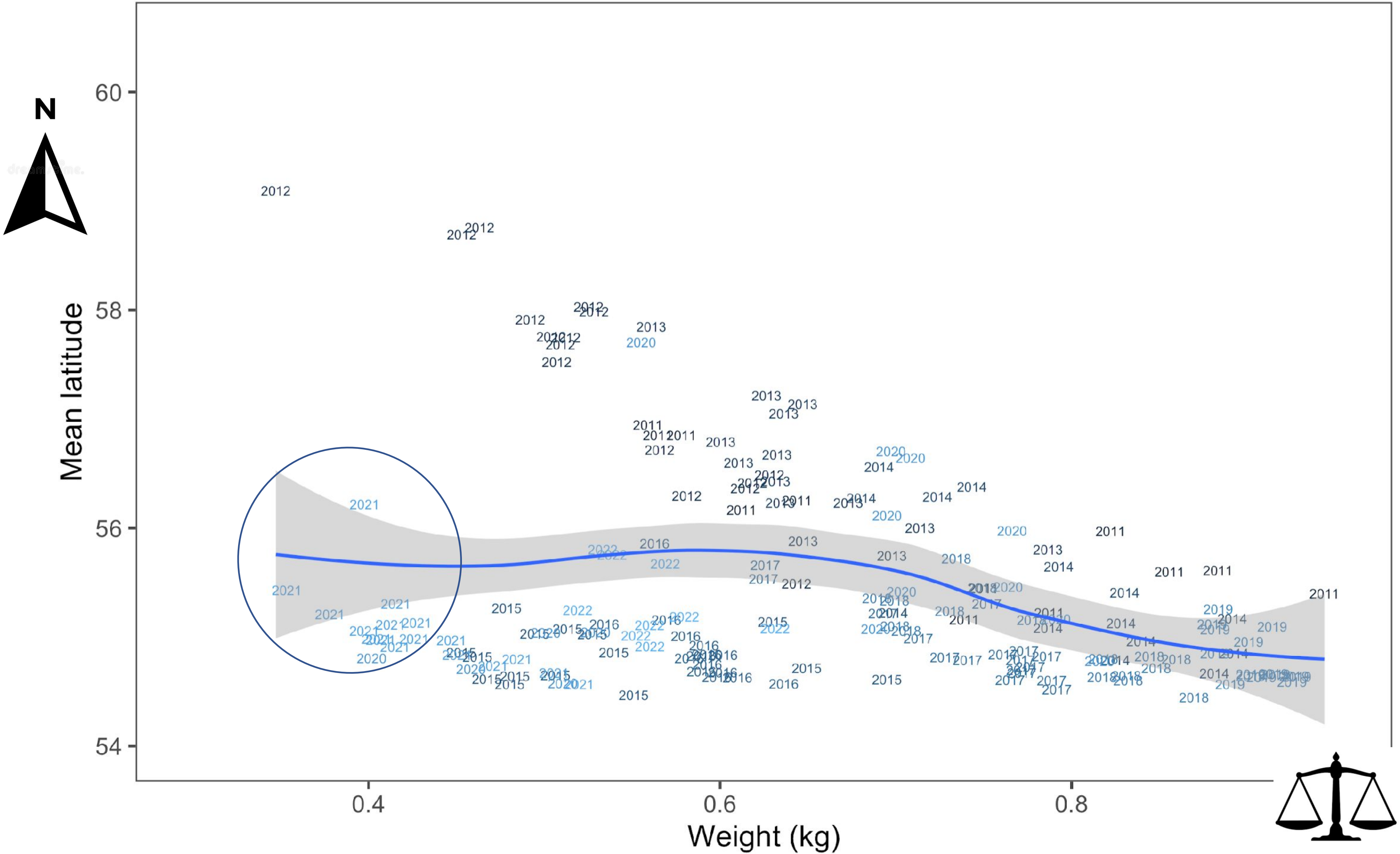
Catcher-processors

B-season catch patterns

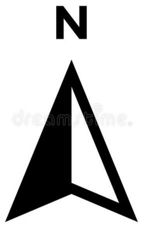


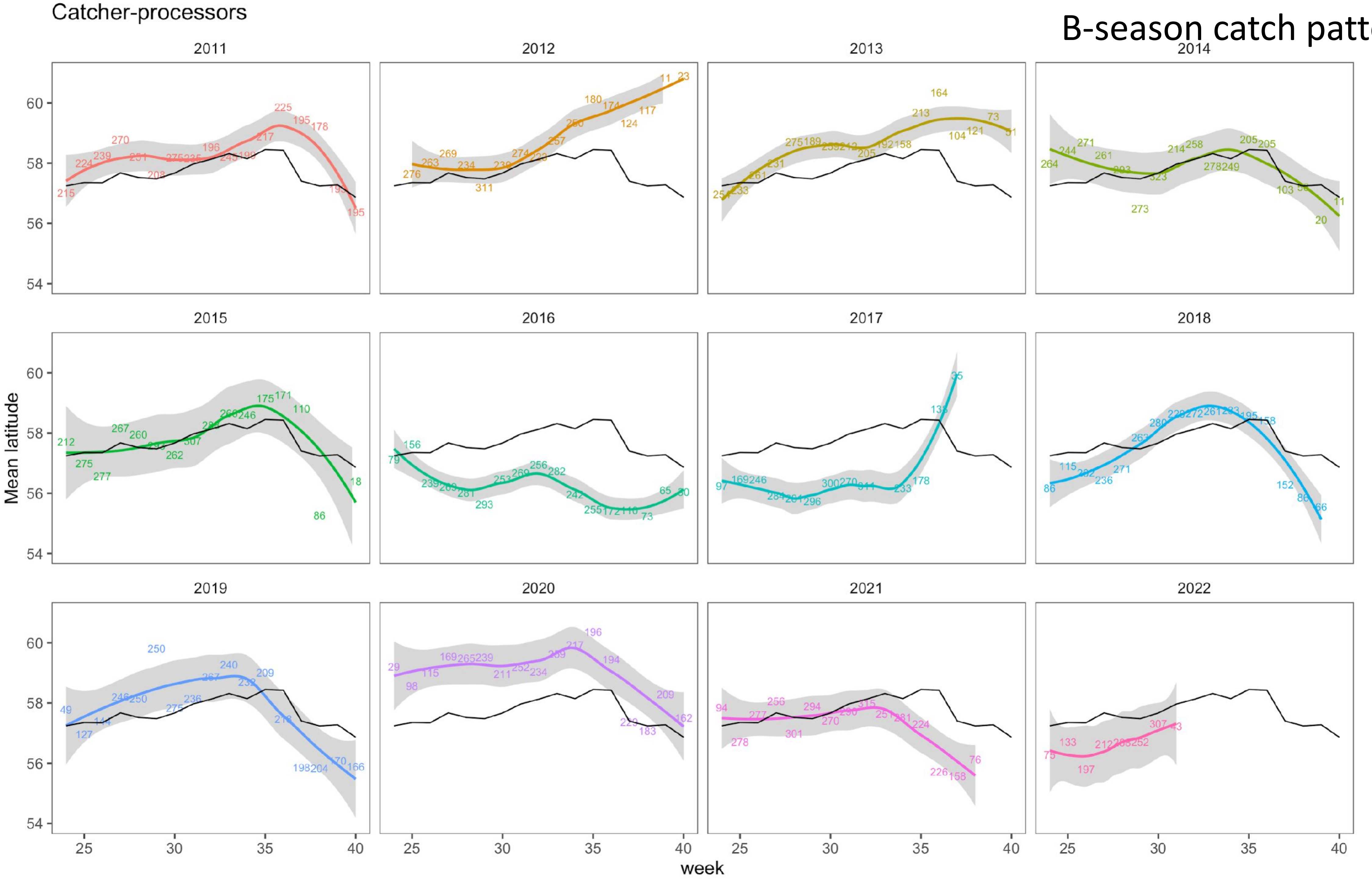
Catcher-vessels

B-season catch patterns



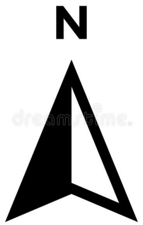
B-season catch patterns

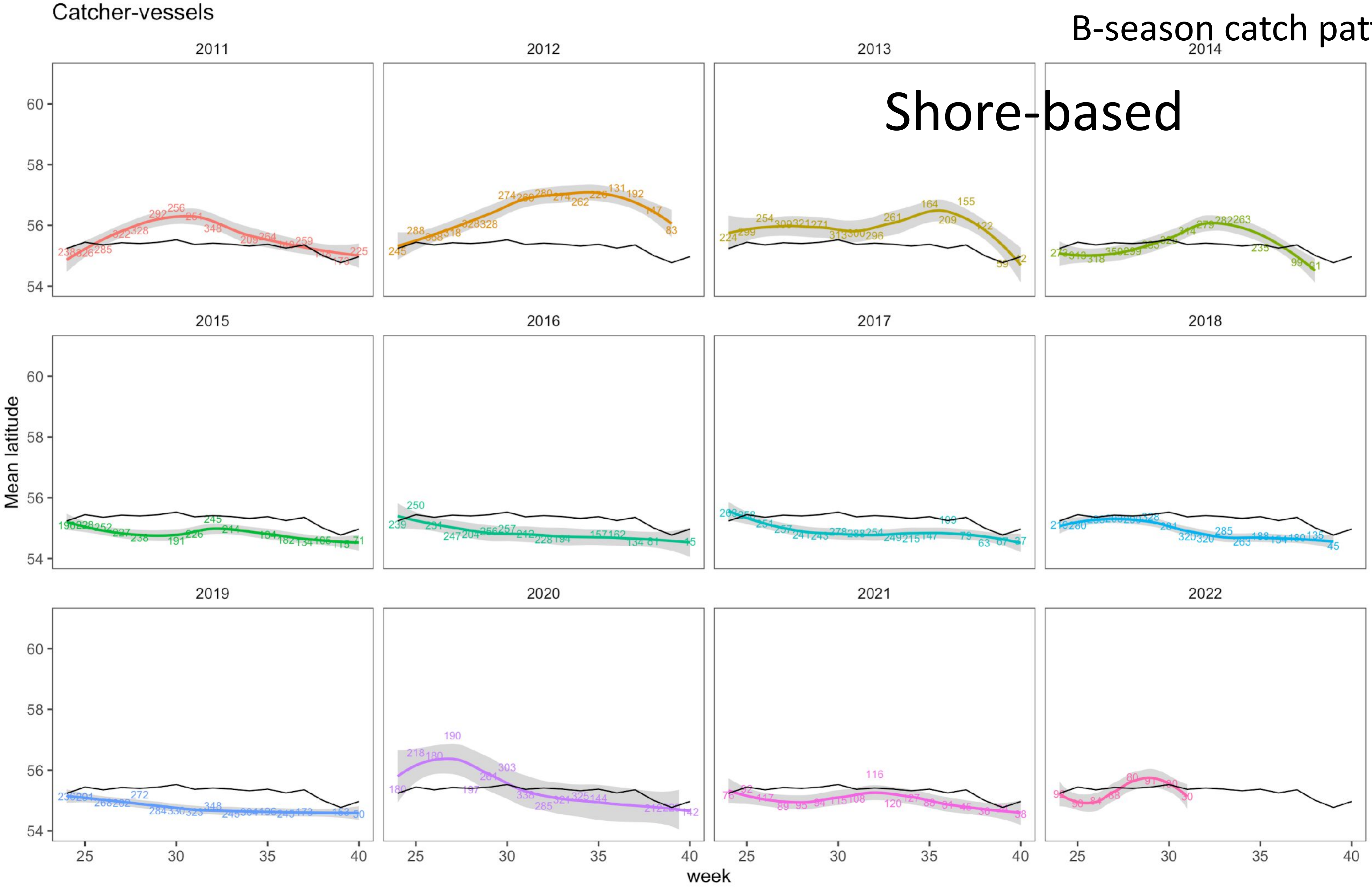


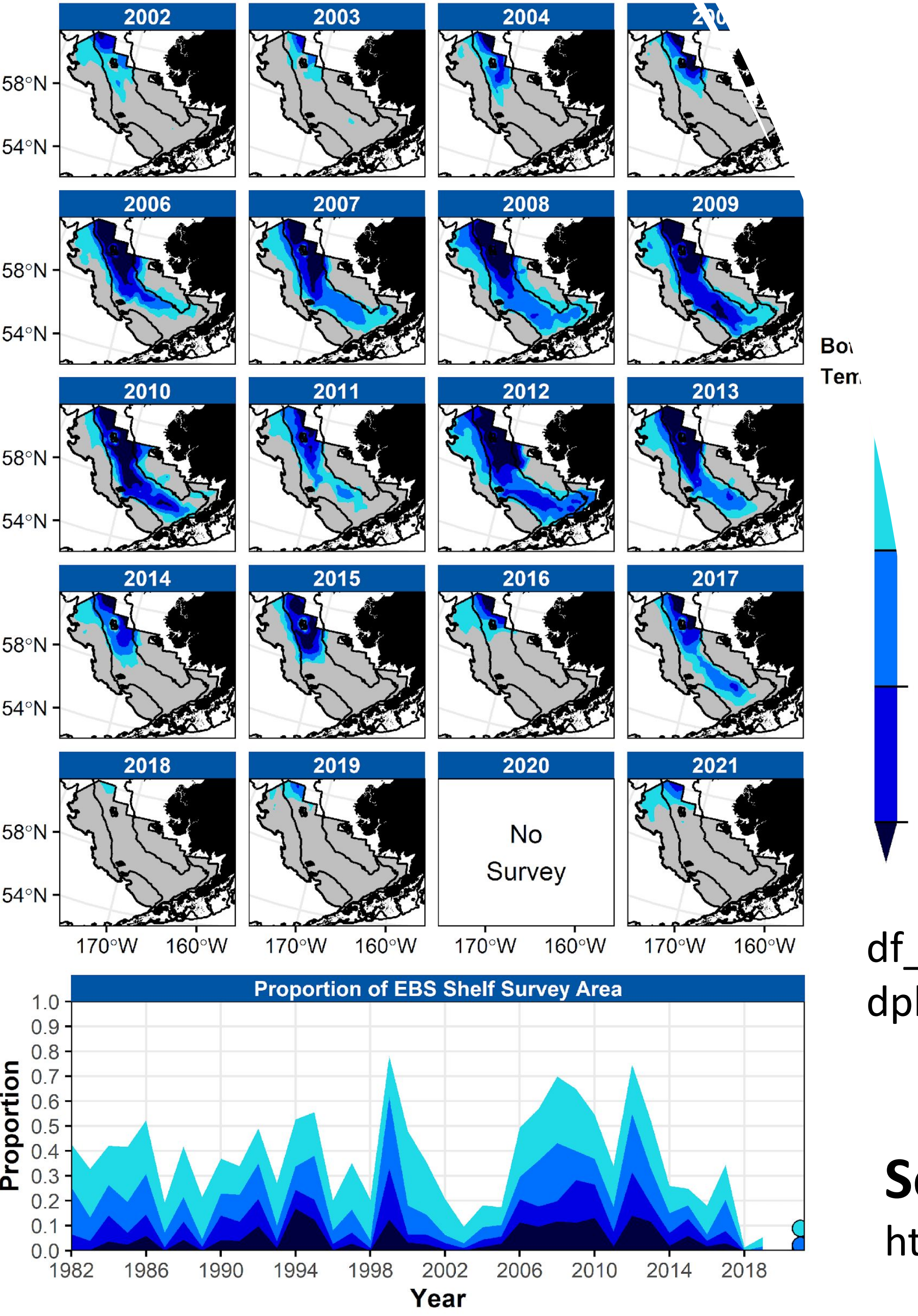


B-season catch patterns

Shore-based







How does it compare to fishery data?

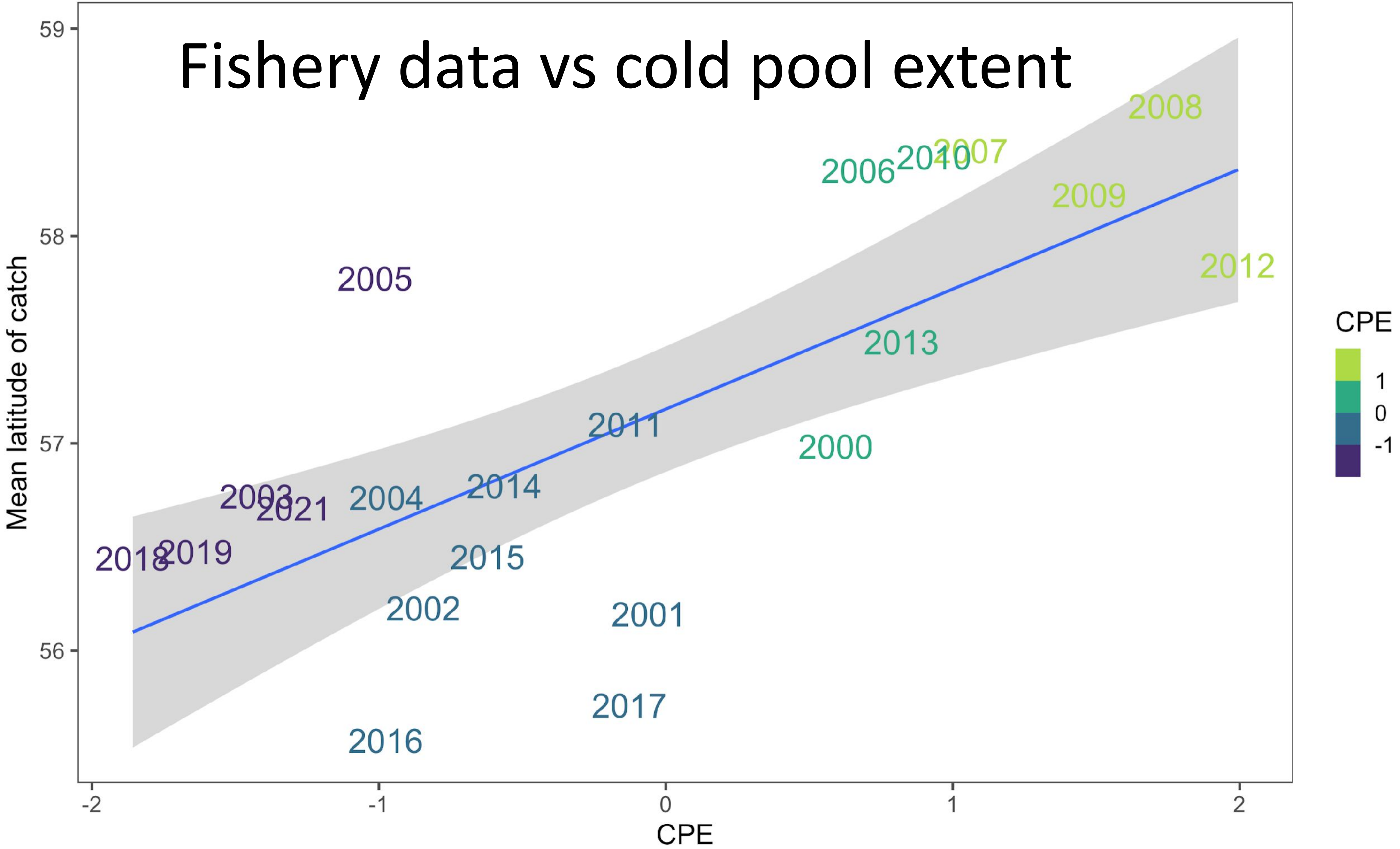
Another survey product: Bottom Temperature

```
df_cpe <- coldpool:::cold_pool_index |>
dplyr::select(year=YEAR,CPE=AREA_LTE2_KM2)
```

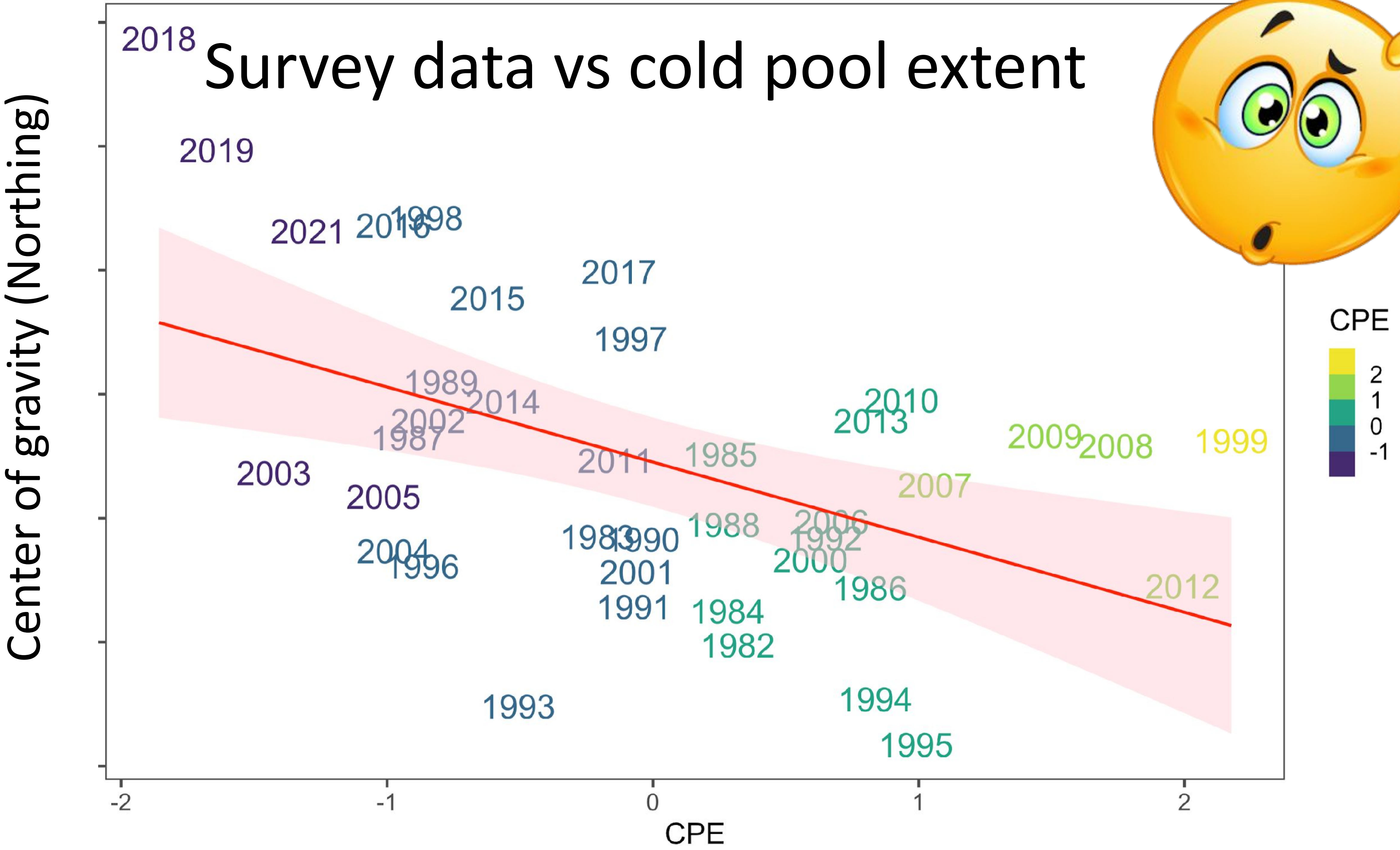
Sean Rohan and Lewis Barnett R package

https://github.com/afsc-gap-products/coldpool

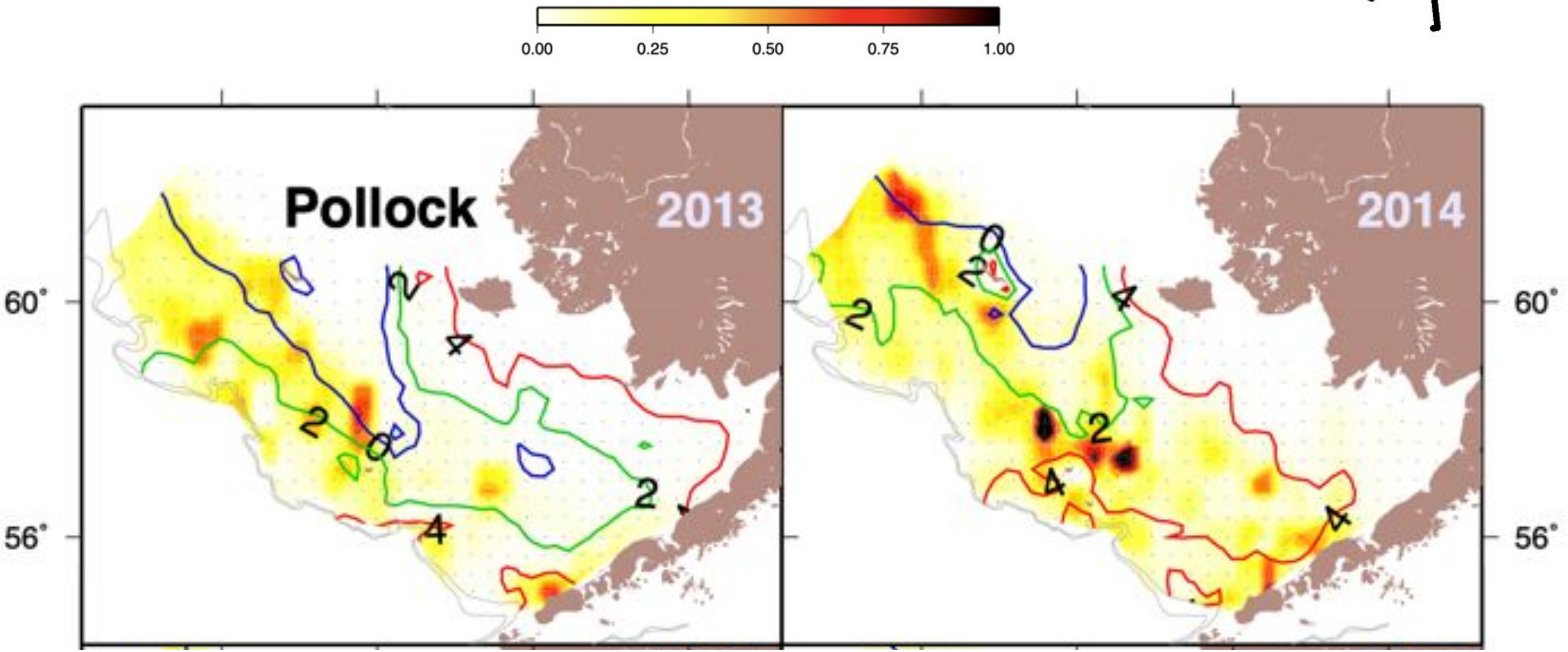
Fishery data vs cold pool extent

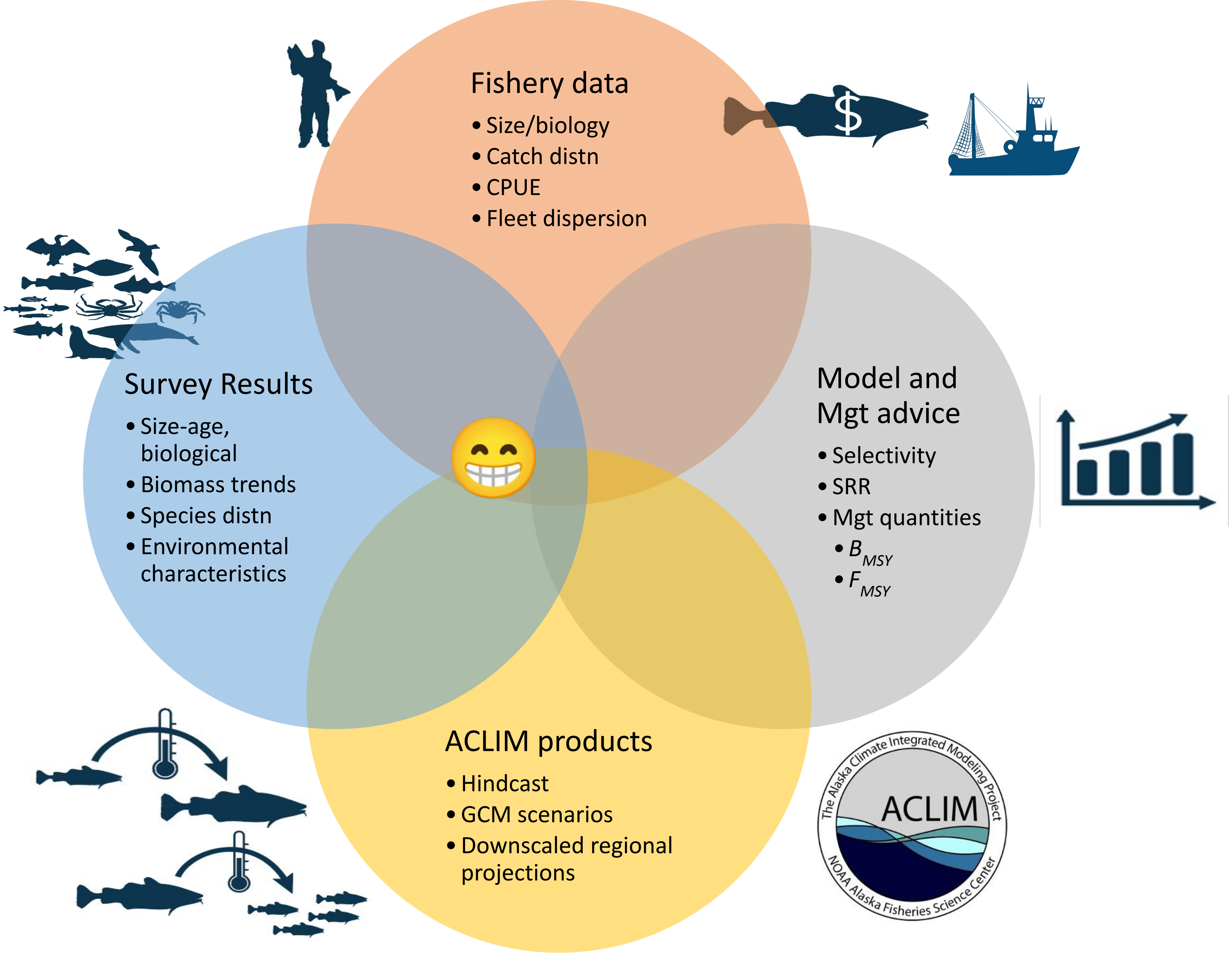


Survey data vs cold pool extent



Relative survey CPUE

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2011 Stock assessment

- EBS pollock

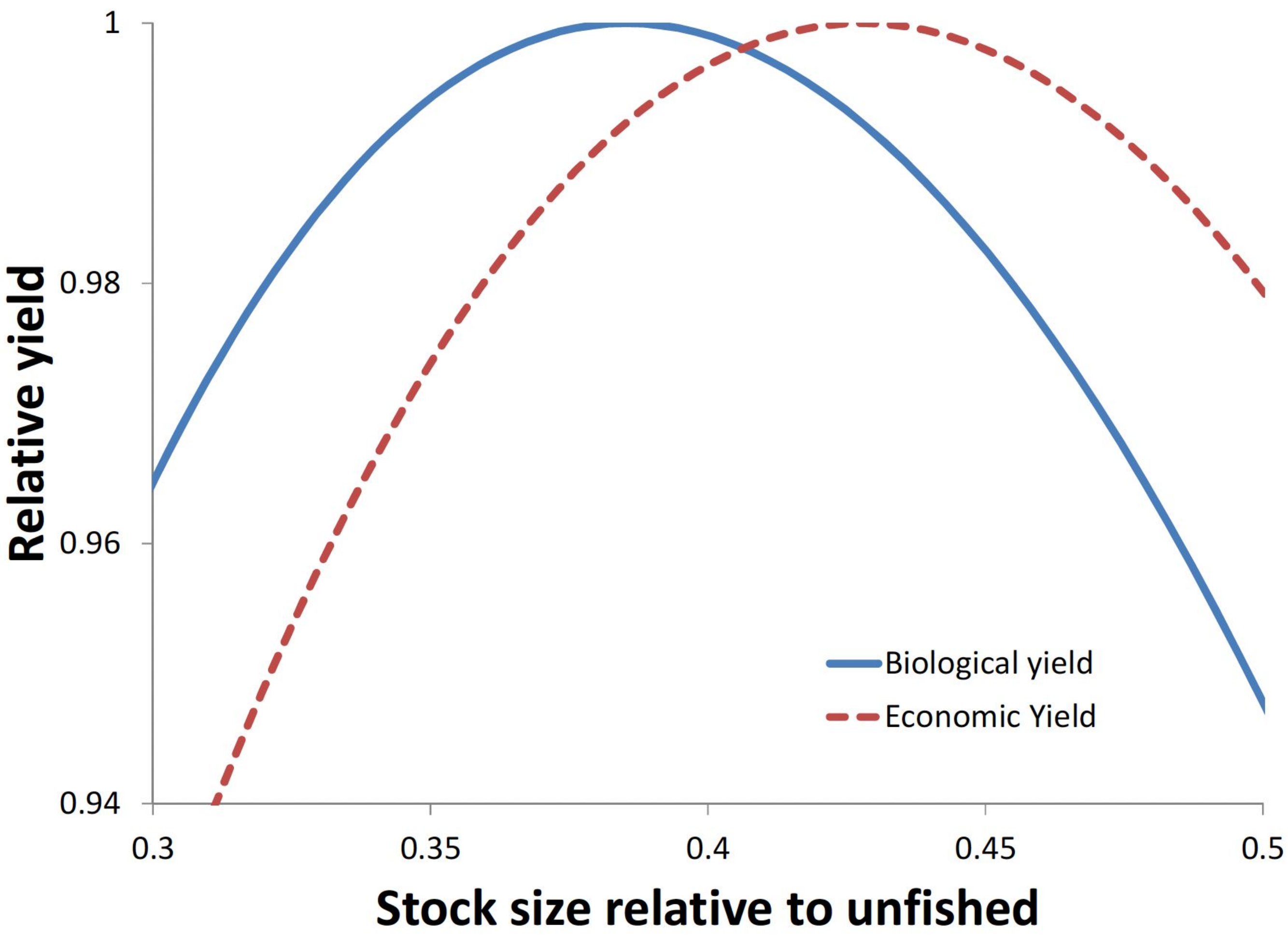
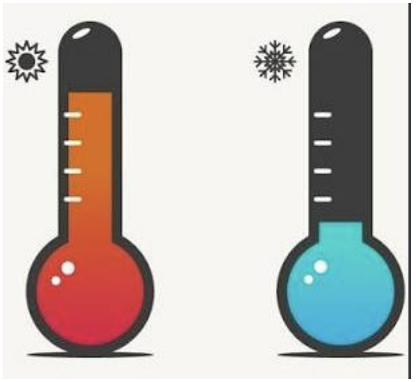
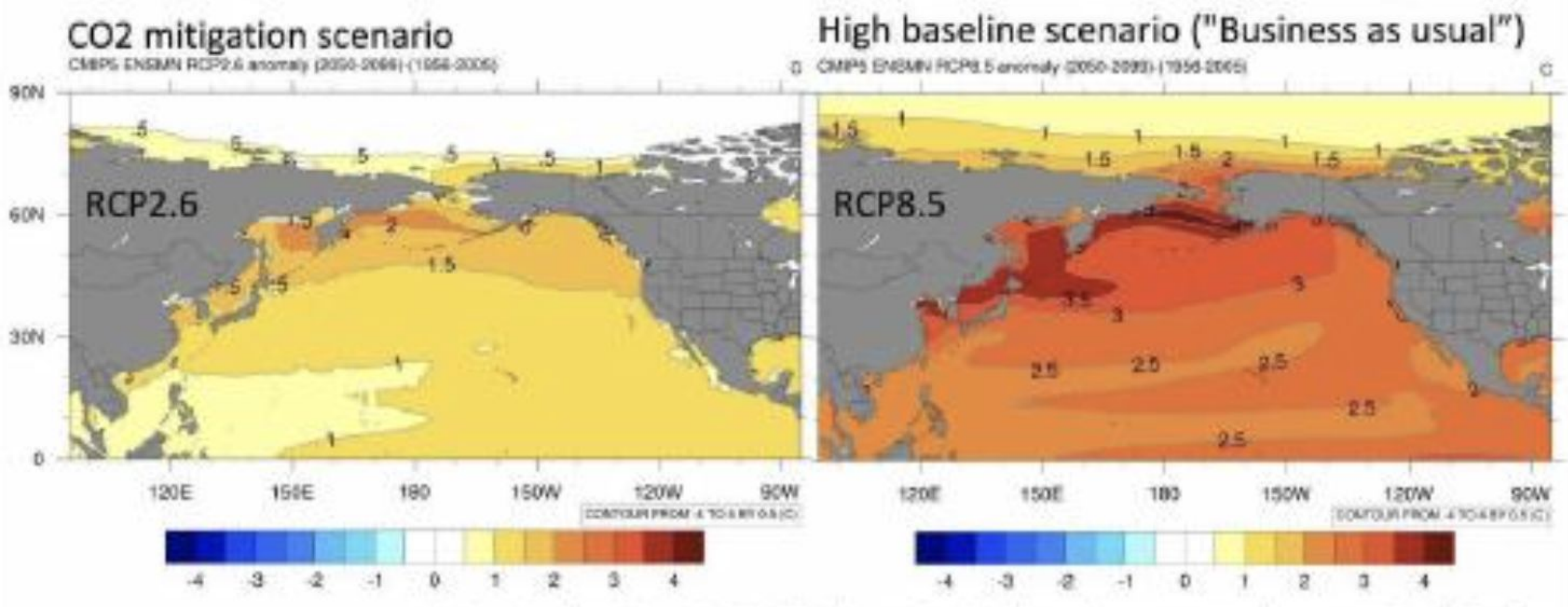


Figure 1.36. Population-level estimated yield curves normalized for biomass (solid line) and economic yield (dashed line). The economic curve uses age-specific with relationship between relative effort (distance) required for capture with a 60-40 weighting and an example age-specific value for ex-vessel landings (slope parameter equal to 0.1).

How may temperatures affect fishing patterns

- And stock characteristics

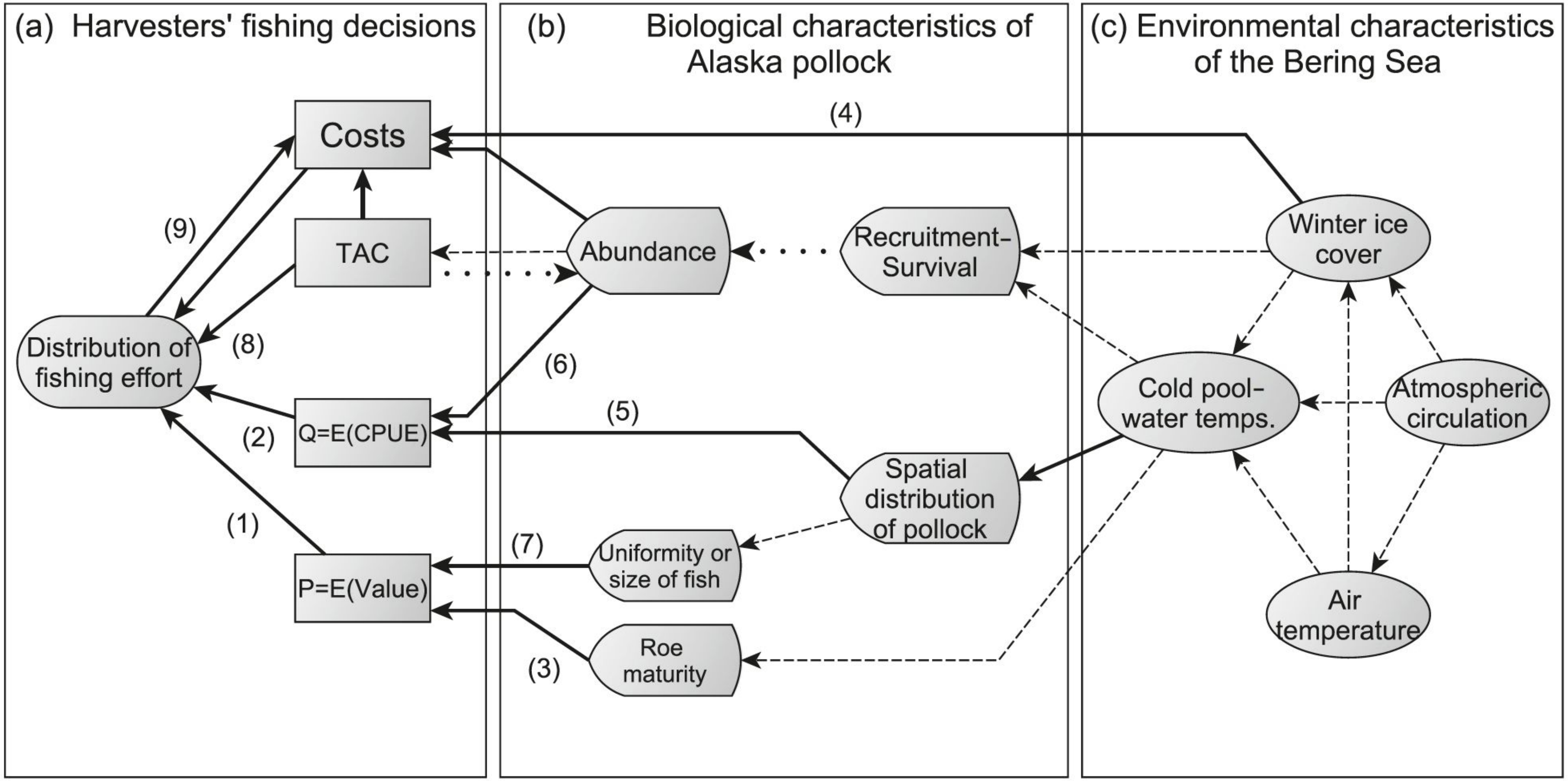




Projection data from CMIP5 (Taylor et al., 2012) avail. at: www.esrl.noaa.gov/psd/ipcc/ocn

Climatic and economic drivers of the Bering Sea walleye pollock (*Theragra chalcogramma*) fishery: implications for the future

Alan C. Haynie and Lisa Pfeiffer



dx.doi.org/10.1139/cjfas-2012-0265

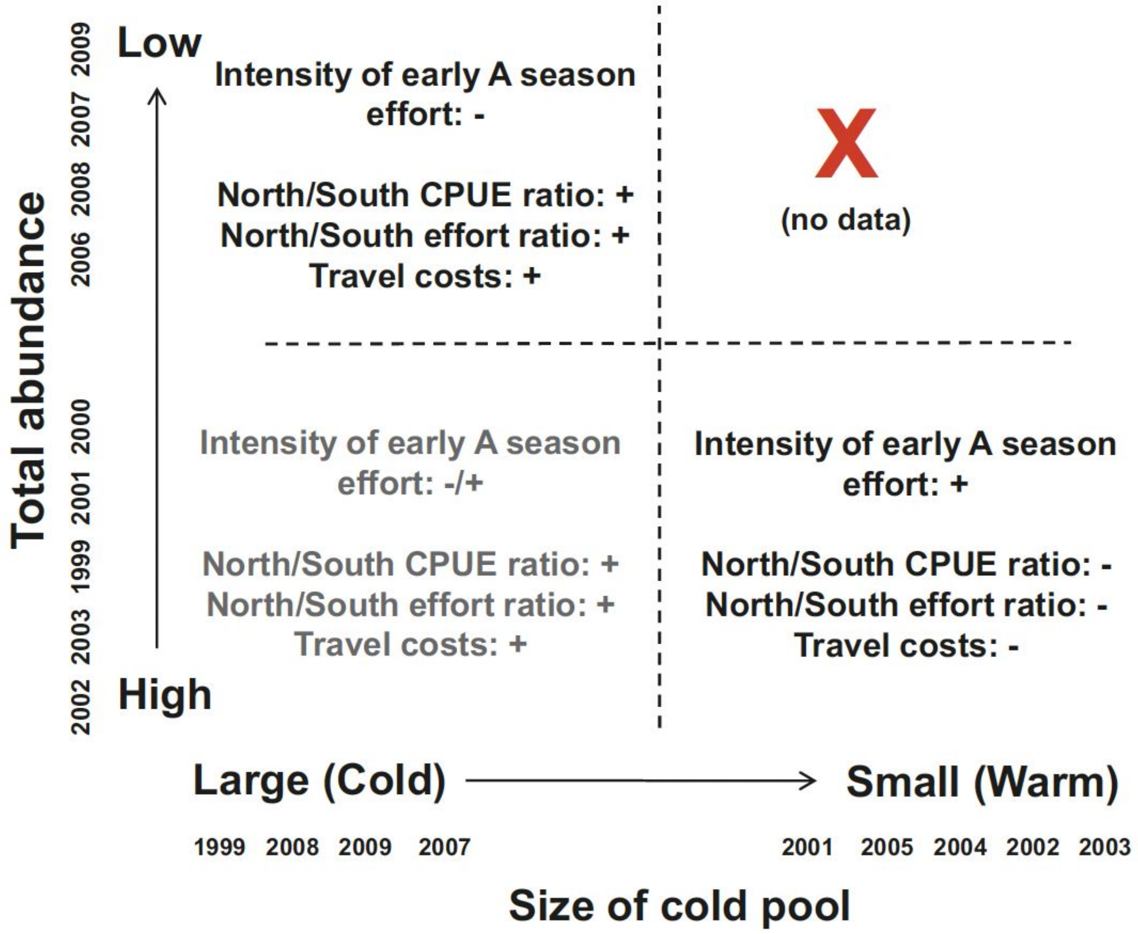
From Haynie and Pfeiffer 2013

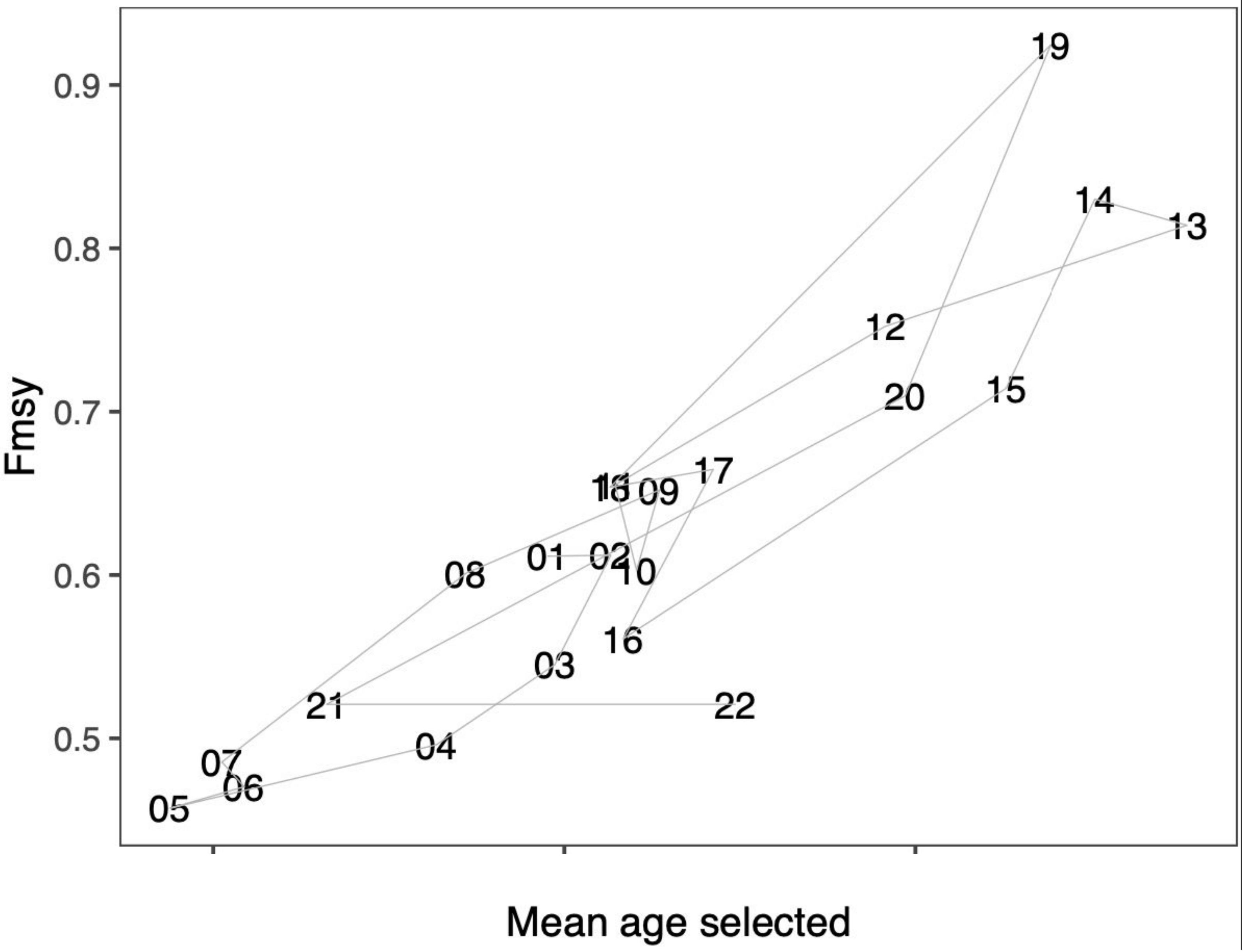
Included CPUE

- Updated

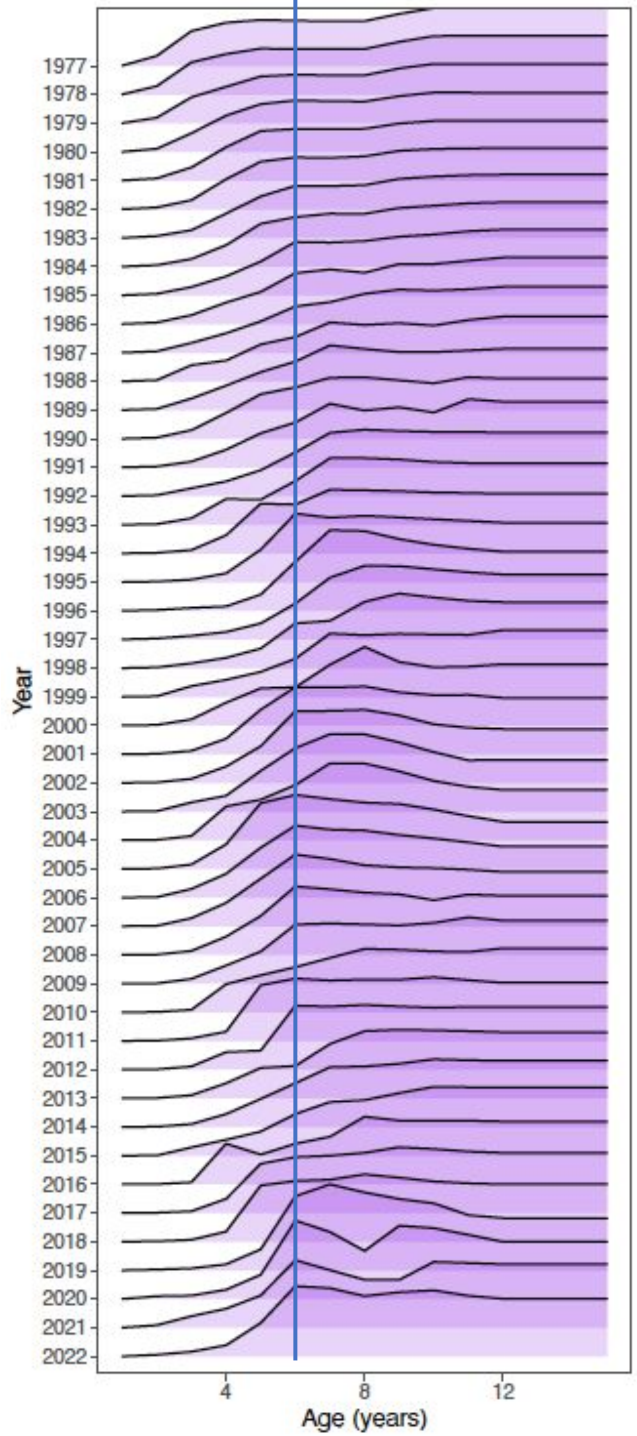
Haynie and Pfeiffer

Fig. 7. Summary of the effects of the size of the cold pool and total walleye pollock abundance on the intensity of early A-season (winter season) effort, B-season (summer season) CPUE, B-season effort, and B-season travel costs. Years in the sample characterized by varying abundance and cold pool levels are listed on the horizontal and vertical axes.





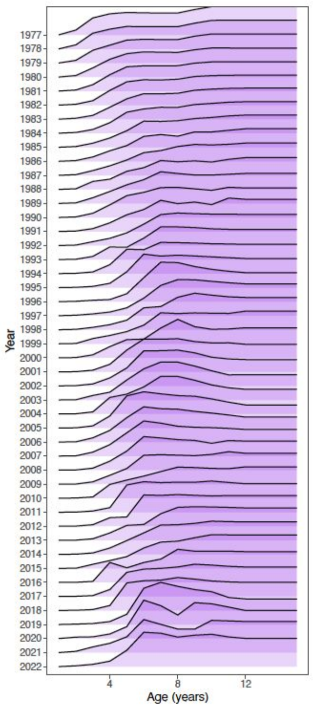
Fmsy
0.9
0.8
0.7
0.6
0.5
Mean age selected
19
14
13
12
20
15
17
09
10
01
02
08
16
03
21
22
04
07
06
05

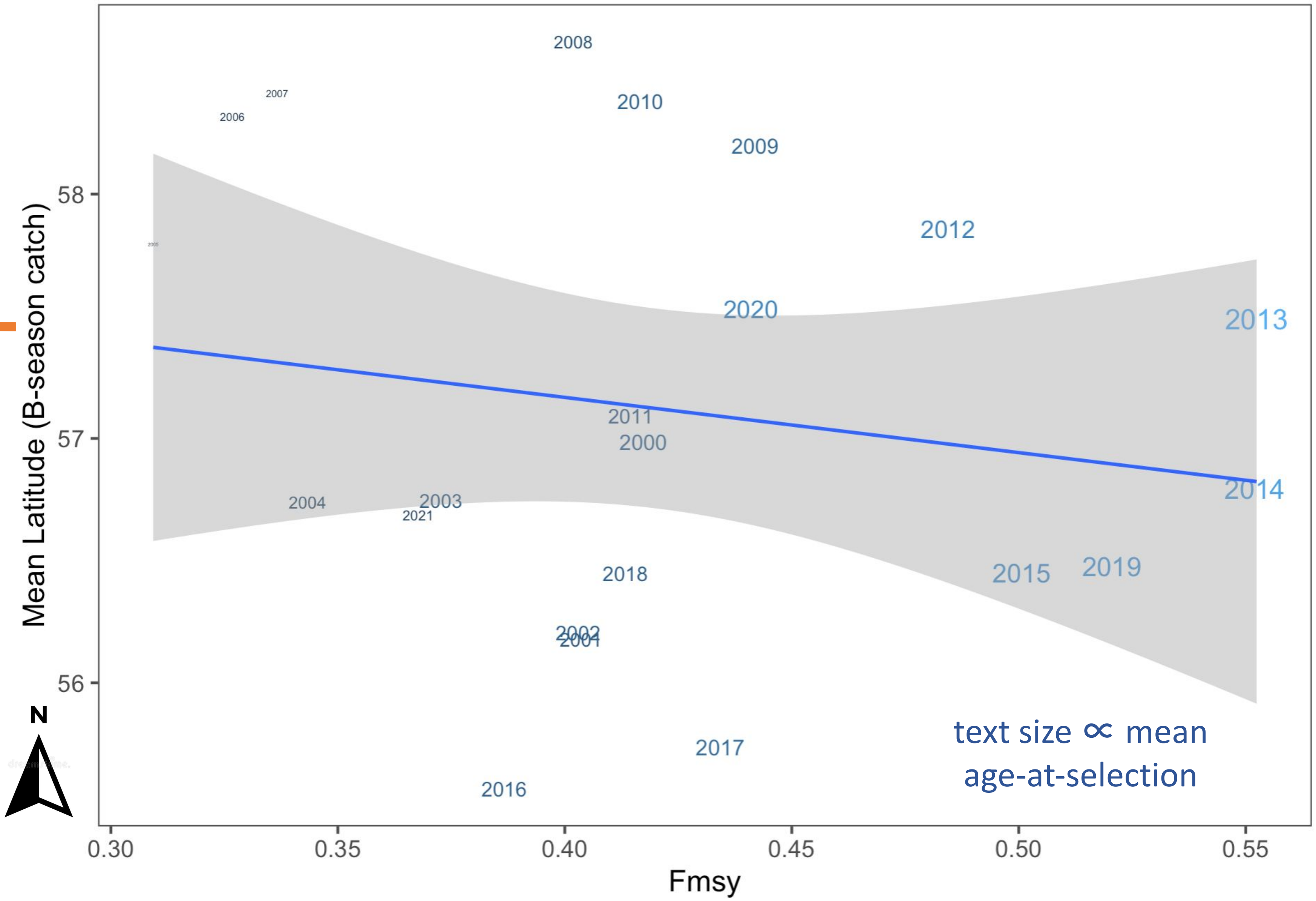


Year
Age (years)
4
8
12
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022

F_{MSY}

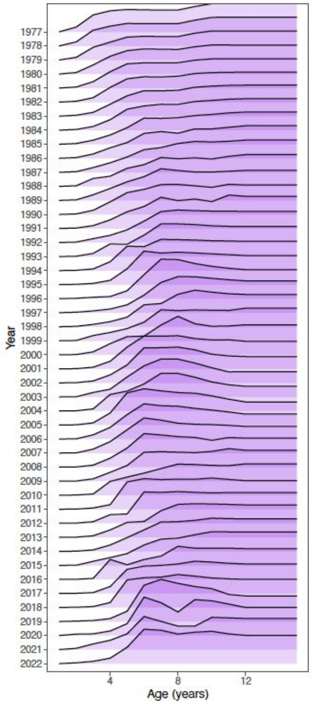
- By year and latitude (and F_{MSY})

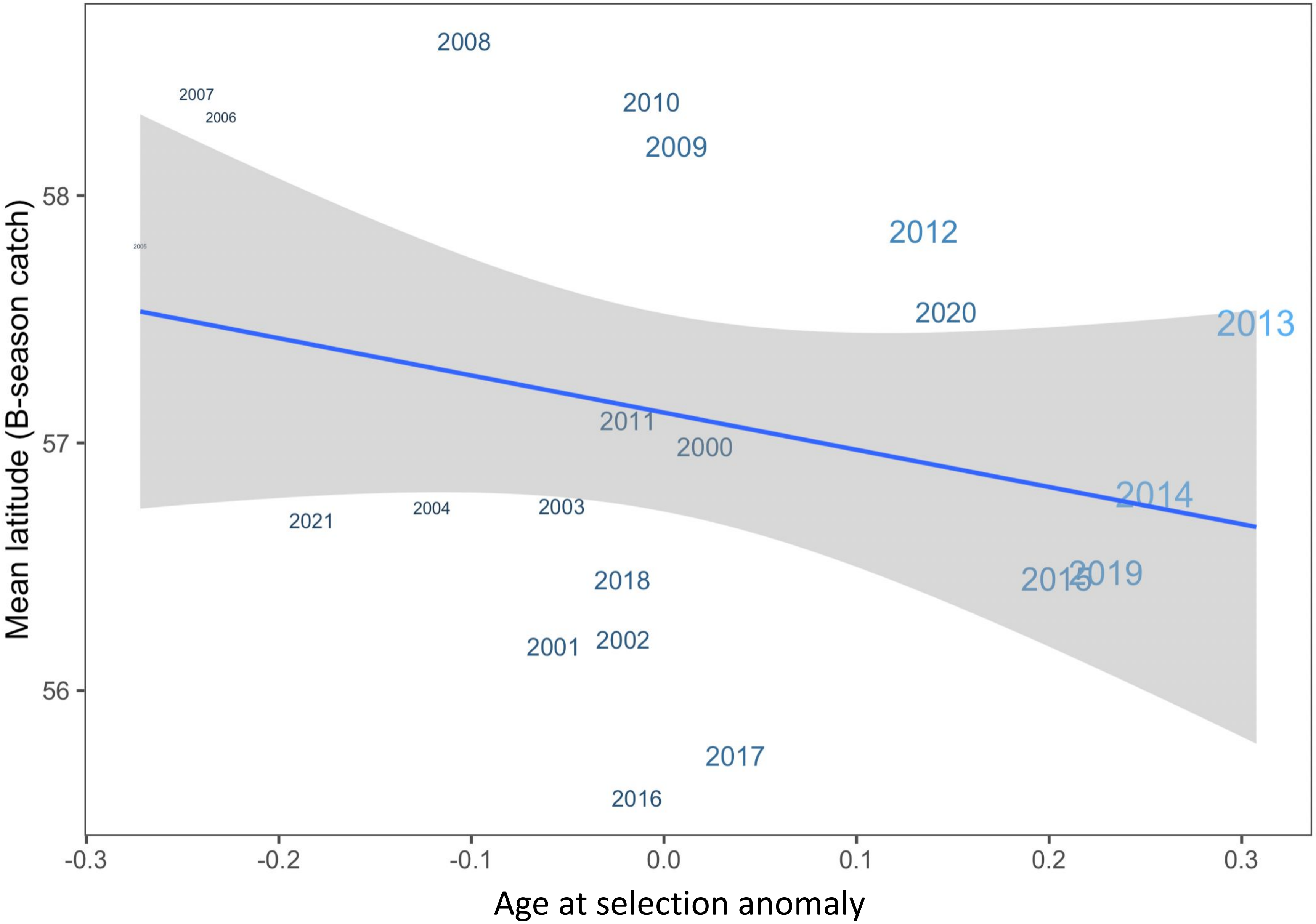


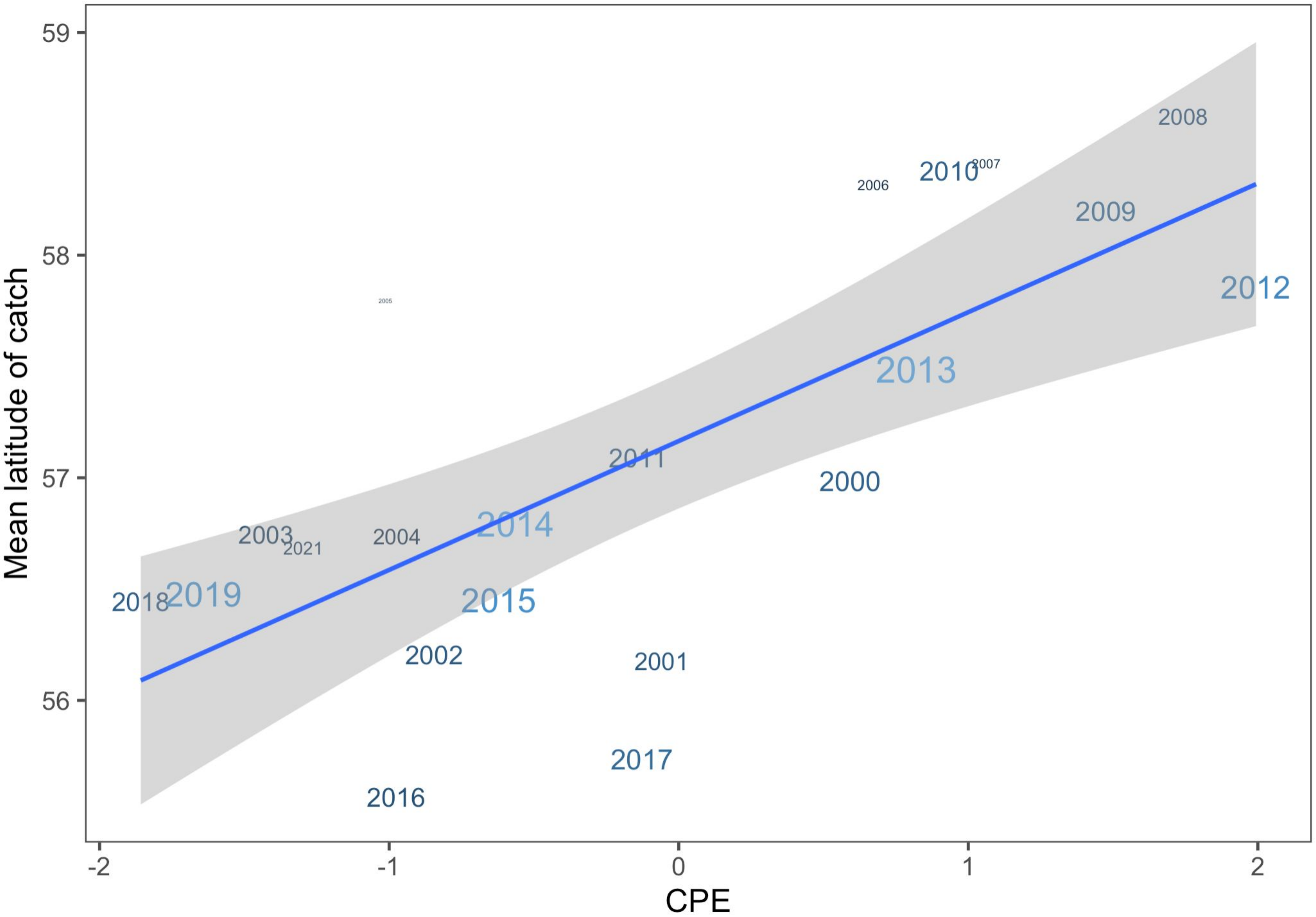


F_{MSY}

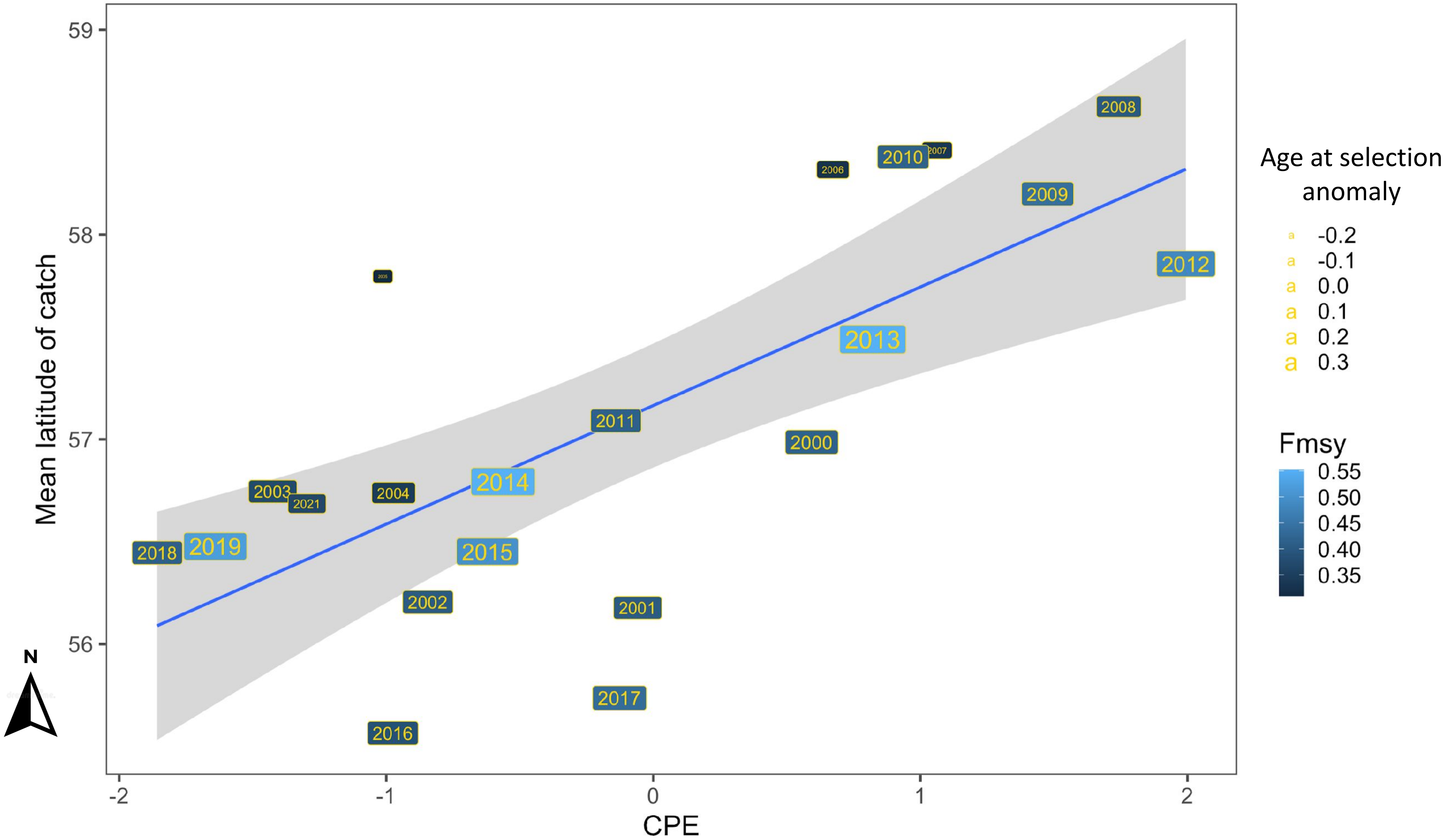
- By year and latitude
  (and mean selected age)

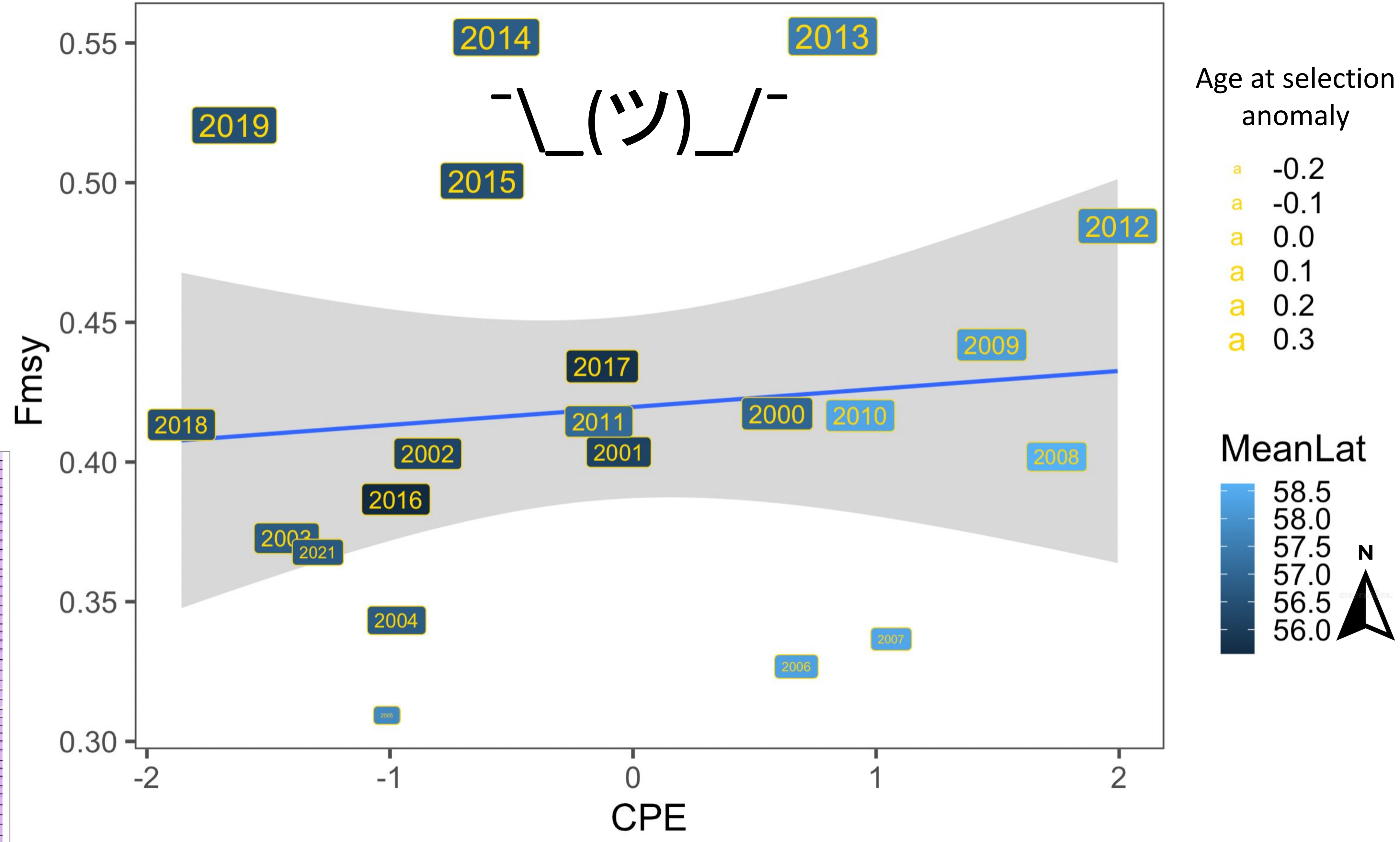


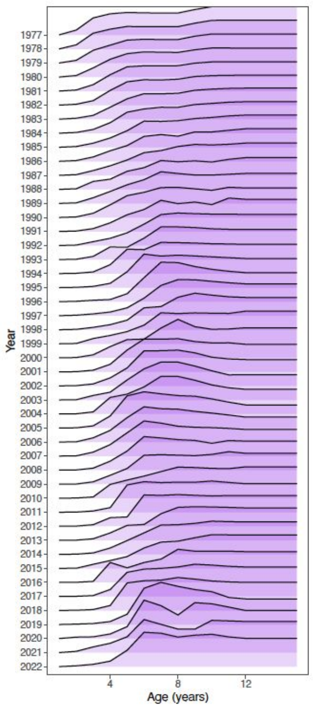




59
58
57
56
Mean latitude of catch
-2
-1
0
1
2
CPE
2008
2006
2010
2007
2009
2012
2005
2013
2011
2000
2014
2003
2021
2004
2018
2019
2015
2002
2001
2017
2016


Mean latitude of catch
CPE
59
58
57
56
-2
-1
0
1
2
2008
2010
2007
2006
2009
2012
2013
2011
2000
2003
2021
2004
2014
2018
2019
2015
2002
2001
2017
2016
N
Age at selection anomaly
-0.2
-0.1
0.0
0.1
0.2
0.3
Fmsy
0.55
0.50
0.45
0.40
0.35


Fmsy
CPE
0.55
0.50
0.45
0.40
0.35
0.30
-2
-1
0
1
2
¯_(ツ)_/¯
2014
2013
2019
2015
2012
2009
2017
2018
2011
2000
2010
2002
2001
2008
2016
2003
2021
2004
2007
2006
2005
Age at selection anomaly
-0.2
-0.1
0.0
0.1
0.2
0.3
MeanLat
58.5
58.0
57.5
57.0
56.5
56.0
N


Year
Age (years)
4
8
12
1977
1978
1979
1980
1981
1982
1983
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1992
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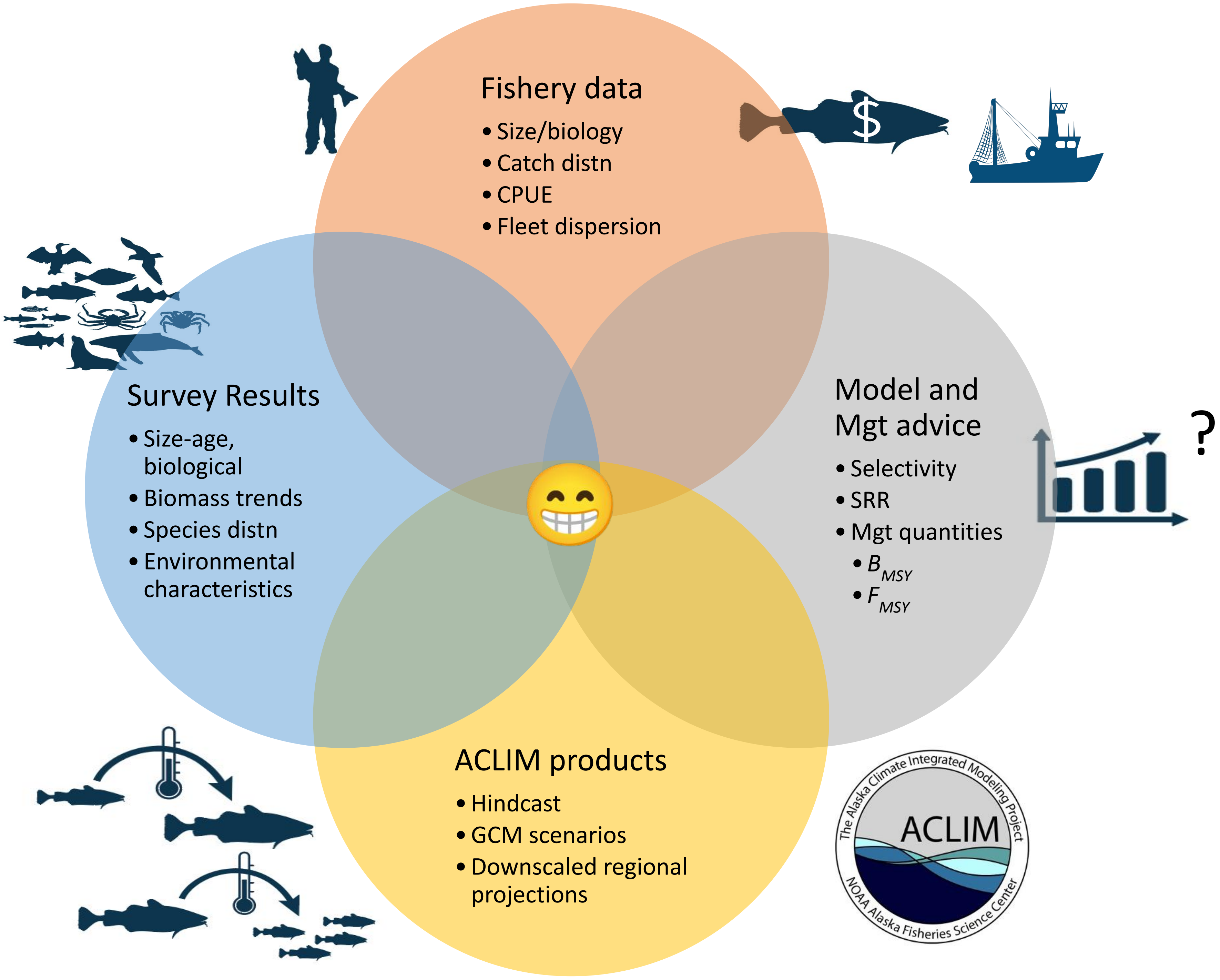
2022



Fishery data
• Size/biology
• Catch distn
• CPUE
• Fleet dispersion
$
Survey Results
• Size-age, biological
• Biomass trends
• Species distn
• Environmental characteristics
Model and Mgt advice
• Selectivity
• SRR
• Mgt quantities
• B_{MSY}
• F_{MSY}
?
ACLIM products
• Hindcast
• GCM scenarios
• Downscaled regional projections
The Alaska Climate Integrated Modeling Project
ACLIM
NOAA Alaska Fisheries Science Center